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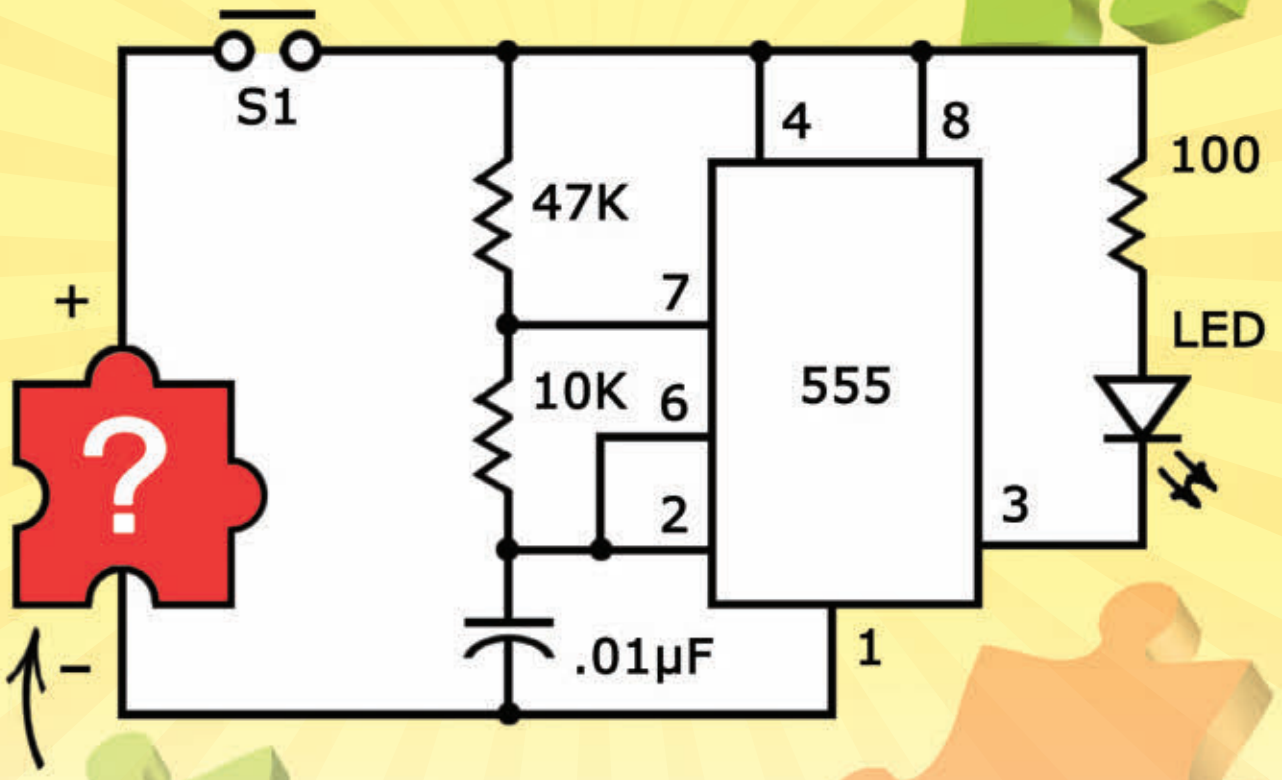

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

The End of the Wristwatch

I appreciate the vintage sound of tube-type guitar amplifiers and the craftsmanship of the old RF wattmeters, with their precision machined, silver slugs. And I have a brass straight key — handmade in West Germany — on my desk. However, as a technology enthusiast, my focus is generally on the future — the next big thing in robotics, microprocessors, sensors, communications, and the like. With rear blinders on, I often forget that in the wake of each new technological breakthrough is a heap of unwanted hardware and software destined for either landfills or third world countries where precious metals are extracted for resale. Not exactly green or even environmentally friendly. Technology adoption is commonly described as a phenomenon in which technology enthusiasts and visionaries first embrace a technology. Next are the early adopters, the early majority, late majority and, finally, the laggards. Odds are, if you're reading *Nuts & Volts*, you're somewhere between enthusiast and early adopter.

Given that rate of technological change is accelerating, the rate of technology abandonment must be accelerating, as well. Furthermore, just as technology adoption is described in terms of the behavioral qualities of the adopters, abandonment follows a predictable pattern. And modeling or at least understanding technology abandonment is important. Why? Because it can help you develop technologies and products that will inevitably displace current technologies. Consider the wristwatch. When the mechanical technology advanced to the point that thin, lightweight pocket watches could be produced economically, the ergonomically superior strap-on watch soon displaced the pocket version. If you're below the age of 25, you're probably not wearing a wristwatch — or a pocket watch. Instead, you likely rely on your cell phone, iPod, laptop, or other mobile electronic device for the date and time. While wristwatches may linger for a few decades as jewelry — most people don't wear a Rolex Presidential because of its accuracy — in a decade or two, the wristwatch will be yet another abandoned technology. Similarly, the increasingly diminutive cell phone, a relative newcomer to the scene, will likely be displaced by the Dick Tracy-styled wrist phone, for the same ergonomic reasons that the watch migrated from the pocket to the wrist.

Will every current technology follow this model of continual, incremental improvement followed by sudden transformation into a new technology? Of course not, but the model provides insight into what's likely to happen. There are inevitably unforeseen twists and turns in the evolution of any technology, and interesting cul de sacs of activity that may linger long after the main thrust of a technology has been abandoned. Consider Morse Code — once a mainstream mode of communications — now used primarily by radio amateurs. After investing years to become proficient at the straight key, one of my first major electronics projects was building a "typewriter" keyboard-based keyer, complete with hardwired ROM — an array of diodes — driven by linear ICs. I followed this project several years later with a CW reader that — using analog circuitry — converted the audible shorts and longs into character strings. Instead of abandoning the Morse Code — which remains my favorite mode of ham radio communications — and moving on to higher-bandwidth, computer based communications, I turned to new technologies to give the old technology new life. As a result of similar actions by tens of thousands of hams, Morse Code has survived longer than it would have from purely economic or practical reasons. While nostalgia may keep some technologies around long after their practical value has waned, in business, economics deal a harsher blow. Like my old fashioned brass keyer, Morse Code has passed from practical technology to nostalgia. As technology enthusiasts, we bear some responsibility for hastily casting aside existing technologies as soon as a faster, smaller, more powerful, or simply more aesthetically appealing version appears on the market. As innovators, we owe it to ourselves to recognize when letting go of the old and embracing the new is the best course of action. **NV**

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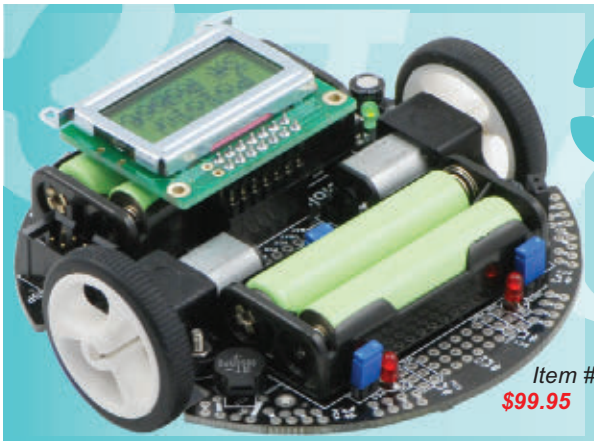

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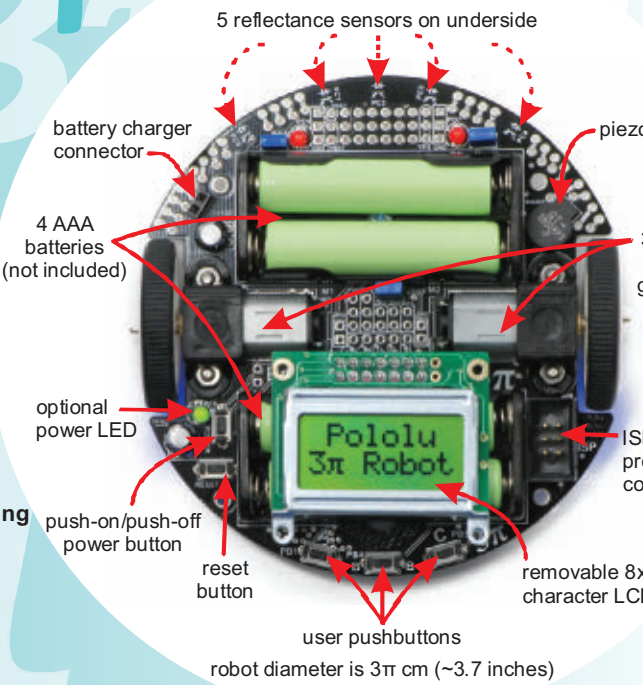

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READER FEEDBACK

STAR-STRUCK BY STEINMETZ

I'm a fairly new subscriber, and I enjoy *Nuts & Volts* greatly. But I especially liked the online article "Steinmetz: Father of Electrical Engineering."

As a longtime electronics amateur who's built dozens of kits over the last 35 years (and experimented on my own), I thought I knew all the stories of the great pioneers like Ampere, Volta, Ohm, Watt, et al. But I admit I've never heard of Steinmetz! Unbelievable!

I liked the article so much that I think it should have been in your print edition. This type of quality research and writing would help newstand sales and future subs. It is also likely that I'll extend my sub, too. My congrats to you and the talented author.

Jim Unger
Philadelphia, PA

ON A DIFFERENT NOTE

Upon reading your blurb on Muzak Newz (April '09 *NV*, p.14), I visited Muzak's website and found they have over 80 channels of music. Only a few of them seem to be syrupy instrumental fare; many more feature rock, pop, jazz, urban, country, and other more hip genres. Frankly, I have not actually heard music in an elevator in almost 40 years, and the place that had it is long gone.

Understandably, most of us who grew up after Elvis Presley hit the scene would prefer to shop, dine, work, and even wait for our healthcare services to music more upbeat than that of The Manovanti Orchestra or Romantic Strings, but what I now hear in most business places today irritates me because it is loud, discordant, and lacks melody. To me, it seems the making of pleasant, relaxing music died with John Denver.

Michael Kiley

Mike — Thanks for the feedback.

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I'm partial to jazz/blues (as a guitarist). — Bryan Bergeron

DEBUG ON DAS BOARD

I enjoyed reading the June '09 Personal Robotics column about Das BlinkenBoard. I myself have been using Atmel microcontrollers for a couple of years now and find them to be very versatile and handy for solving almost any control function with very few parts.

I noticed on the circuit board that the programming control signals brought out to the jumper connectors J1 through J3 make it possible to program the part with the SPI programming mode, but don't allow for debugging. If you had brought out the Reset and Vcc pins as well, then on-board debugging would be possible in addition to on-board programming, if you ever get around to a new board layout.

Barry Mead

Hi Barry! Thank you for taking the time to write. I'm really glad you enjoyed the article.

*You're in luck! We won't have to make a *new* board layout to handle this. One of the design criteria for our original Das BlinkenBoard was to be programmable and "debug-able" without having to pull the chip from the socket. The trick is you have to make a "breakout" adapter for the six-pin Atmel programmer. Check the photos at this link for a schematic and an example "hexopus" cable (i.e., like an octopus cable, but with six instead of eight pins):*

http://picasaweb.google.com/VernGraner/DasBlinkenBoardUpdates#

Once you have the adapter made, you use the top row of the J1-J3 jacks, the +5 and Reset pins to the left of the J1-J3 jacks, and then use one of the GND pins below the J1-J3 jacks. You can then reprogram/debug the board without having to remove the chip. I hope this information helps.

Vern Graner

LIT UP BY BLINKENBOARD

I received my copy of *Nuts & Volts* in the mail today and was fascinated with the June '09 Personal Robotics column on Das Blinkenboard. I run a web page and a discussion group for those interested in the Burroughs B-205 computer.

The B-205's console is one of the great Blinken Lights icons of the 1960's and 70's TV and movies. I hope to create a Blinken Lights board to simulate the lights on the B-205 console.

Stan Brewer

http://tech.groups.yahoo.com/group/B205/

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continued on page 87

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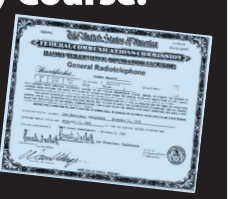

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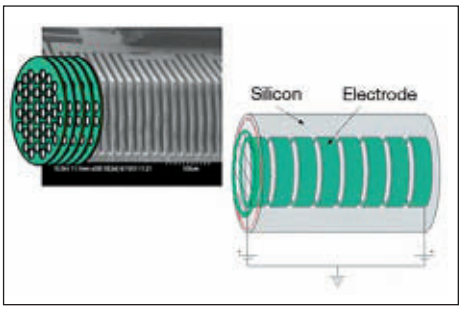
TECH KNOWLEDGEY 2009

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

TOWARD HARNESSING ANTIMATTER



■ The antimatter trap is composed of a stack of wafers with tiny holes that line up to form the tubes.

■ Weber and Lynn tinker with their 3-MV deuteron accelerator.

As you probably know, whenever an electron encounters its antimatter counterpart (a positron), the two annihilate each other, giving off pure energy in the form of gamma rays. And quite a bit of energy, too. Just 0.3 mg of antimatter (about twice the size of a grain of sand) has the same energy potential as 1,700 tons of liquid rocket fuel. On that basis, it has been calculated that it would take only about 2 mg of antimatter contained in a 10-lb trap to shoot some astronauts into deep space. The problem is that three things are required to make that happen: (1) lots of positrons, which are in short supply in this part of the universe; (2) a container to keep them in; and (3) a way of using their annihilation power in some sort of engine. Until recently, items 2 and 3 had proven elusive.

Some time ago, Prof. Kevin Lynn and Marc Weber, two researchers at Washington State University's Center for Materials Research (**www.cmr.wsu.edu**), figured out how to solve the first one: With a handy, dandy 3-MV deuteron accelerator, they create positron beams that can generate up to 10 trillion usable particles per day. Until recently, the containment problem was considered to be unsolvable, but it appears that they have taken care of that one, as well.

Because like charges repel, the energy required to contain the required billion or so positrons would exceed the energy generated in annihilation, so your net gain would be less than zero. But one night it occurred to Lynn that you don't necessarily have to keep them in the same enclosed space. You could just line them up in an infinitely long and narrow vacuum tube. Then he realized that if you cut the tube into a batch of tiny straws — each containing a single positron — you would arrive at the solution. With the help of a few megabucks of federal funding, Lynn and Weber have come up with a prototype trap — roughly the size of a Coke can — that can hold an array of 10,000 tubes, each 0.1 m in length and 100 m in diameter. The goal is to eventually scale this up to a trap that's big enough to power a spacecraft. With that kind of drive, astronauts could just keep going faster and faster until they reach the speed of light. Unfortunately for NASA, the third hurdle has yet to be cleared but, according to Lynn, "Like lasers and transistors, both of which had their skeptics when first invented, harnessing positrons could open up a universe of unexplored ideas and uses. It could happen in your lifetime."

NANOCRYSTALS: LET THERE BE (CHEAPER) LIGHT

It is widely known that some molecules and small crystals can absorb and give off photons, which makes them potentially useful as light sources. But generating a continuous flow of light has been impossible because of an optical phenomenon called "blinking." Apparently, a typical nanocrystal has a choice of emitting energy in the form of light or heat, and it periodically chooses the latter and goes dark. But in May, it was announced that Todd Krause of the University of Rochester (**www.rochester.edu**), working with Keith Kahen, a scientist at Eastman Kodak (**www.kodak.com**), had created a nonblinking nanocrystal. The two, in

■ New nonblinking nanocrystals may replace OLEDs.

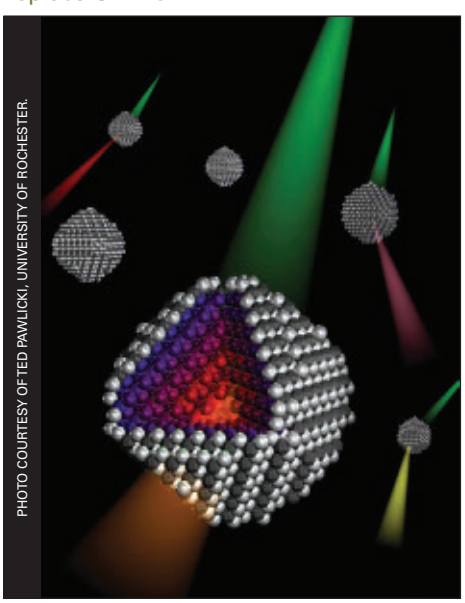


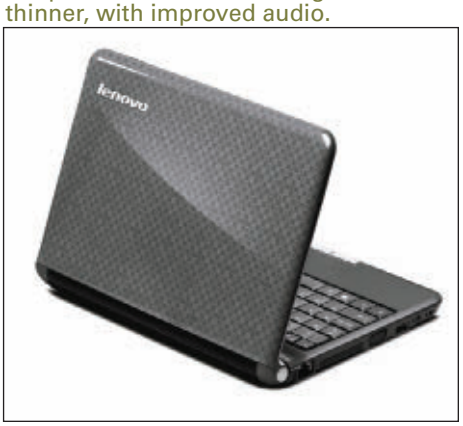
PHOTO COURTESY OF TED PAWLICKI, UNIVERSITY OF ROCHESTER.

a search for low-cost light sources similar to organic LEDs but without the short lifespans and manufacturing problems inherent in these devices, had been experimenting with different nanocrystal compositions. At some point, they realized that the blinking effect occurs because standard crystals have a core of one semiconductor wrapped in a shell of another one, with a distinct boundary between the two. They theorized that a new type of nanocrystal that uses a continuous gradient between the semiconductors might be blink-free. Lo and behold, their substance — using a core of cadmium and selenium that transforms into a shell of zinc and selenium — did the trick. That gradient squelches the processes that prevent photons from radiating, resulting in a stream of emitted photons that's as steady as the stream of absorbed ones. This opens up the prospect of lasers and lighting that will be extremely cheap to manufacture and more efficient in operation. An interesting aspect is that the new nanocrystals can be manufactured to emit any color light that you want. You only need to vary their size. According to Krauss, it should be possible to "paint" a grid of variously sized nanocrystals onto a flat surface, giving us things like paper-thin computer displays or walls that light your living room in any desired color.

COMPUTERS AND NETWORKING

NETBOOK UPGRADED

■ Updated S10 netbook is lighter and thinner, with improved audio.



Lenovo (**www.lenovo.com**) has upgraded its S10 netbook line with the S10-2, which is lighter, thinner, and fitted with more operational features. According to the company, "With the netbook scene rapidly changing, consumers are telling us they want to merge the capabilities of their most commonly used sources of electronic entertainment, such as digital photographs, online TV, music, and social networks into one portable and affordable device. We've incorporated that feedback into our new IdeaPad S10-2." Specifically, it has a larger keyboard, three USB ports, and Dolby headphone technology for improved audio performance. Through your favorite headphones, you can hear surround sound audio from 5.1 channels. An interesting feature is Lenovo's QuickStart application which allows users to listen to music, view photos, and send IMs or make Skype calls without booting the operating system. Instead of typing in a password, you can log on using the built-in video camera and VeriFace face recognition technology. The device also provides a 30 percent boost in battery life, with up to six hours operation between charges. The S10-2, featuring an Intel Atom processor and a 10.1-inch LED display, starts at $349.

GRAPHICS CARD BREAKS 1 GHz BARRIER

A few weeks ago, Advanced Micro Devices (**www.amd.com**) introduced a factory overclocked version of its ATI Radeon HD 4890, said to be the world's first graphics card to break the 1 GHz barrier using standard air cooling. The new model uses advanced GDDR5 memory and the faster clock speed to deliver 1.6 TFLOPs of computing power, allowing it to deliver new levels of general-purpose GPU-accelerated performance in ATI Stream applications such as video transcoding and post processing.

■ The AMD Radeon HD 4890 now runs at 1 GHz.

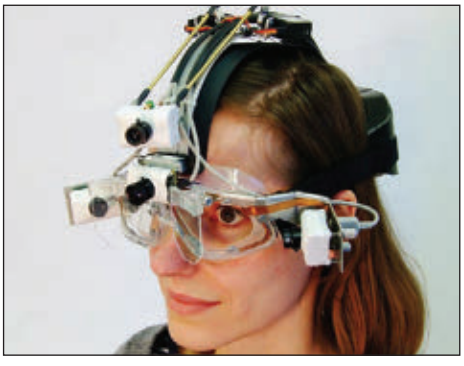
According to AMD, the card delivers a top-notch gaming experience in the latest games, including DirectX® 10.1 titles. In addition, it features support for open standards such as OpenGL3 with DirectX® 10-like hardware extensions and the recently ratified OpenCL specification. The 4890 also supports advanced game physics. The card is supported by a dozen add-in-board companies offering a variety of custom board and cooling solutions. Technology partners include ASUS, Club 3D, Diamond Multimedia, Force3D, GECUBE, Gigabyte, HIS (Hightech Information Systems), ITC, Jetway, MSI, Palit Multimedia, PowerColor, SAPPHIRE Technology, and XFX.

APPLICATION TRACKS STIMULUS EFFECTS

One of the little details Congress forgot to address in the $300 billion stimulus package last February is how anyone can track where the gigabucks went and what their effect was. Apparently, the legislation places that burden on state officials who receive the money, but there isn't much specific guidance. Recipients are simply required to (1) allocate funds wisely and quickly, (2) efficiently track and manage incoming funds from various federal agencies, and (3) assess, manage, and report on the progress of funded projects. Pretty much what you'd put in the thank-you note to Aunt Zelda for your birthday check. But never fear. Several software companies are

selling applications to take care of everything, including the folks who brought you Windows Vista. Microsoft says its Stimulus360 program can do all of the above plus "provide intuitive views of the data for different audiences," which sounds a little like bureaucratese for "spin the data different ways to satisfy different blocks of voters." It also "supports key performance indicators (KPIs) and other government-backed performance metrics, automated workflow, and comprehensive analysis across consolidated data sources." Cool. I'll bet it can also prioritize parallel logistical flexibility and optimize systematized transitional organizational contingencies. According to the publisher, "If it's vital to government, it's mission critical to Microsoft." I feel better already.

CIRCUITS AND DEVICES



■ The EyeSeeCam interface, developed at the University of Munich.

EYE-TO-ROBOT INTERFACE DEMONSTRATED

If you think people look dorky in bifocals, take a look at EyeSeeCam, recently demonstrated at the Hannover industrial fair in Germany. Developed at the University of Munich, it's a head-mounted interface that uses infrared LEDs, transparent mirrors, and video cameras to track the wearer's eye movements. It transmits the tracking data to servo actuators that then drive things like video cameras, electronic devices, and robots. You can even use it to automatically transmit an image of exactly what you are seeing to a nearby PC, which would make it useful for things like documenting surgical procedures. Initially designed for the study of cognitive behavior, the developers are now looking at commercialization possibilities. Other projected applications include newscasts, security and special forces training, making home movies, and controlling robotic heads. The image quality doesn't appear to be overwhelming at present, with a maximum frame size of 752 by 480 pixels, but it offers sampling rates up to 600 Hz. Technical details are sketchy as of this writing, and the **www.eyeseecam.com** website is still under construction. But all you need to run it is a laptop with a Firewire port, and it is billed as lightweight (170 g) and low in cost (no price specified yet).

■ Artist's conception of the underwater bot. ©DFKI Bremen, used by permission.

TOUCHY-FEELY UNDERSEA BOT

This isn't on the market yet, either, but some folks at the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research (**www.ifam.fraunhofer.de**) and the German Research Center for Artificial Intelligence (**www.dfki.de**) have developed an underwater robot with a sense of touch provided by specially designed strain gauges. When the bot encounters an obstacle, a gauge is distorted, which changes its electrical resistance, and the bot reacts accordingly. The interesting thing is that the strain gauge, which is only a few tens of micrometers thick, is printed directly onto curved surfaces of the robot. As a result, many can be applied in close proximity, and the bot can tell exactly where the obstacle is

INDUSTRY AND THE PROFESSION

INTEL FINED $1.45 BILLION

Yes, you read it right: 1.45 billion smackers. A few weeks ago, the European Commission (**ec.europa.eu**) found Intel guilty of abusing its position in the x86 microprocessor market and announced that the company had "harmed millions of European consumers by deliberately acting to keep competitors out of the market for computer chips for many years." Specifically, the EC stated that (1) "Intel gave wholly or partially hidden rebates to computer manufacturers on condition that they bought all, or almost all, their x86 CPUs from Intel," (2) Intel made payments to major retailer Media Saturn Holding from October 2002 to December 2007 on condition that it exclusively sold Intel-based PCs in all countries in which Media Saturn Holding is active," and (3) Intel "interfered directly in the relations between computer manufacturers and AMD. Intel awarded computer manufacturers payments — unrelated to any particular purchases from Intel — on condition that these computer manufacturers postponed or cancelled the launch of specific AMD-based products." This follows a similar finding in 2008 by the Korea Fair Trade Commission, which levied a fine of $25.4 million, and a 2005 ruling by the Japan Fair Trade Commission that Intel had violated that country's anti-monopoly laws. Intel can probably take the hit, having 2008 revenues of $37.6 billion and a net income of $5.3 billion, but still ...

touching it. This is a nice feature for operation in deep and murky environments where a vision system wouldn't work well. The mechanical quadrupus is intended for such tasks as offshore drilling rig maintenance and deep-water sediment sample collection.

FIGHTING IC OBSOLESCENCE

If you're building a long-lived product line that doesn't need to be redesigned all that often, you may find it problematic that many IC lines are going obsolete, particularly in such SMT packages as PLCCs, TSOPs, QFPs, SOICs, etc. But a solution is offered by Interconnect Systems, Inc. (**www.isipkg.com**), in the form of its FlexFrame™ adapters. The FlexFrame consists of phos-bronze pins loaded into an FR4 carrier and bent to imitate the gullwing or j-leads on the IC. The connector is soldered between the adapter and the PCB to create the interconnect. According to ISI VP Mark Gilliam, "IC obsolescence is a growing issue with our customer base, and we are currently designing two to three new products each week. Our modules and adapters have been qualified for use in high-reliability applications including military, aerospace, telecom, networking, server, and industrial markets." The adapters are priced from $1 to $20, depending on complexity and volume. **NV**

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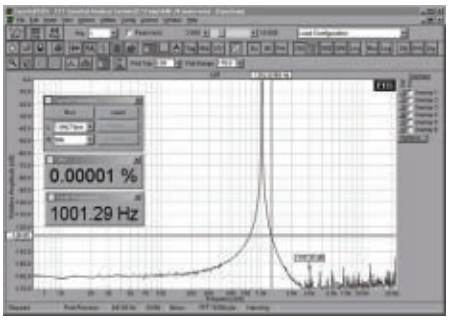

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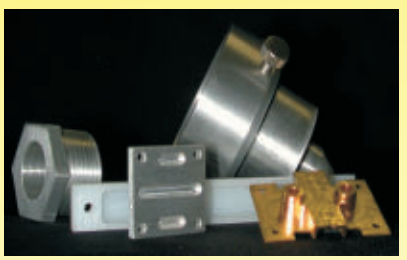

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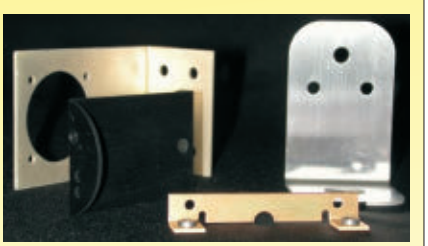

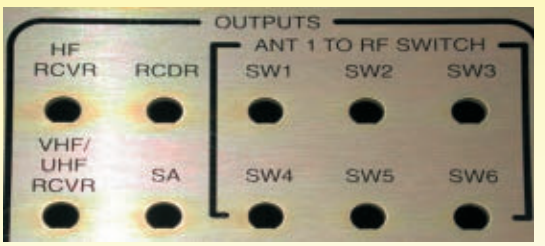

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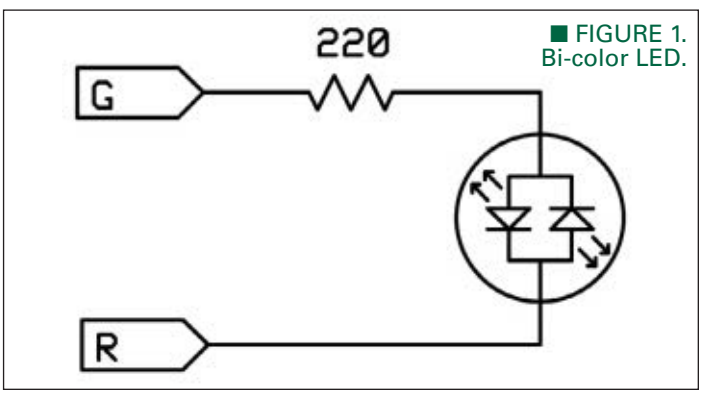
■ BY JON WILLIAMS

LOVING LEDs AGAIN

I OFTEN TELL FRIENDS THAT ARE just getting into microcontrollers that if they can learn to control an LED, they can learn to control just about anything. Now, most of those friends are prop builders and, for the most part, are just looking for simple on and off control; a blinking LED easily becomes a pneumatic piston raising and lowering some element of a special effect. I recently used a bi-color LED in an SX-based product design and it was a big hit – the product and the use of the LED. With a simple, green and red LED, I was able to communicate the state of the machine and our customers loved it. Program space, however, prevented me from taking the LED control code as far as I wanted to. Well, with a whole cog at my disposal that is no longer an issue ... I am loving LEDs again!

The fact of the matter is that we humans are reasonably trainable (if you're a girlfriend, housewife, or mother you're probably shaking your head in disagreement at the moment, but bear with me). This statement is especially true when new training is built on established skills or information. For example, we often use the color green for "go" or "okay;" red means "stop;" yellow means "caution" – of course, all of this depends on context. In recording devices, green usually means "play" and red means "record." As product designers, it is in our best interest to take advantage of previously-established training so that our customers can adapt to the new product more quickly.

The product I mentioned earlier is a digital recorder and playback device designed for prop and animatronics control. When armed for playback, the mode LED is green; when playing a recorded sequence, the LED flashes green; I used motion (blinking) to indicate that the device is active. When a channel is armed for recording, the mode LED is red; when recording is in progess, the LED flashes red. I'm sure this seems terribly obvious as you're reading it now, but how many products have you dealt with that didn't use obvious choices like these?



■ FIGURE 1. Bi-color LED.

BUILDING AN LED CO-PROCESSOR

Since the early days of BASIC Stamps, we've become accustomed to adding application-specific co-processors to enhance a project; things like servo controllers and serial LCDs – they're so common now that we take these things for granted. One way to think of the Propeller is a 32-bit processor with seven built-in co-processor engines that we can do with as we please. Neat, huh?

In my SX project, the LED control code was part of the ISR (interrupt service routine) so it had to be very trim; this limited the features I could include to color and basic on-off blinking. What I really want is the ability to control color, do colorized blinking, and have

BILL OF MATERIALS

Item	Description	Supplier/Part No.
w LED1	Bi-color, green/red	Mouser 78-TLUV5300
w R1	220	Mouser 299-220-RC

brightness control of the LED. That's what we're going to do with the Propeller. We'll start simply and build as we go until we have the full-featured driver.

The hardware for this project is simple: a resistor and bi-color LED that you probably have in your parts drawer. You can solder these together for the Propeller platform or plug them in if you're using the Propeller demo board or PPDB.

THREE COLORS FROM TWO

The two-lead, bi-color LED actually has two LED chips inside (green and red) wired back-to-back. This arrangement allows current to flow through just one element at a time. It turns out that if we reverse current flow quickly through the bi-color LED, it can appear yellow, giving us a third color and — in total — four states: off, green, red, and yellow.

Here's the rub: Green and red LEDs are constructed from different materials and have different forward voltages. On my LED, the green chip had a forward voltage of 1.75V and the red chip had a forward voltage of 1.56V. With a 220 ohm resistor and a 3.3V output from the Propeller, the green LED would get about 7 mA and the red LED would get about 8 mA — it's enough to make a difference and you can clearly see it when reading the forward voltage with a multimeter.

So, what does this mean? Well, it means that we cannot get yellow by simply reversing the current direction every other cycle. What we're going to do is construct the code such that we can easily control the green to red cycle ratio to get the best approximation of yellow.

Okay, then, let's jump into the code. You'll remember from last time that Propeller assembly code (PASM) segments are defined in a **DAT** section of a Spin program. We'll start with the interface which lets us define the pin to use for the green anode (red will be green plus one) and the color state for the LED.

```
DAT
              org       0

leddriver     mov       tmp1, par
              rdlong    tmp2, tmp1
              mov       gMask, #1
              shl       gMask, tmp2
              or        dira, gMask

              mov       rMask, gMask
              shl       rMask, #1
              or        dira, rMask

              add       tmp1, #4
              mov       colorAddr, tmp1
```

The driver starts by copying the cog's **par** (parameter) register to *tmp1*; what we're going to pass in **par** is the address (using @) of the variable that holds the green anode pin number (this is the starting address of all the parameters we will pass to the driver). With **rdlong**, we can read the pin number from the hub RAM into the cog variable called *tmp2*. What we want to do is create a pin mask for the green pin; to do that, we'll load *gMask* with one and then shift left by the pin number in *tmp2*. To make that pin an output, we'll **or** the pin mask onto the **dira** register as **dira** controls the pin's I/O direction (one bit = output; zero bit = input).

In the program, we're going to specify that the red anode pin is the next pin up from green, so creating the red mask is easy: We copy the *gMask* into *rMask* and then shift *rMask* left by one bit. As with the green pin, we make the red anode pin an output by **or**-ing the pin mask onto **dira**.

At this point, *tmp1* is equal to **par** which is the address of the green pin variable. The second parameter for the driver is the color mode. To get the hub address of the color mode variable, we can add four (four bytes in a long integer) to *tmp1* and copy that into *colorAddr*; we'll use this variable in the program to update the LED color.

With the driver setup [mostly] out of the way, we can get into the main loop. In this version of the driver, we don't need any specific loop timing but it doesn't hurt to add it in to support timing functions to come later. Loop timing in assembly is usually a nightmare of cycle counting but the Propeller relieves us of that nightmare by including an instruction called **waitcnt** which takes care of the dirty work.

Remember that all cogs are driven by a common clock and have access to the system counter. In both Spin and PASM, the **waitcnt** instructions will wait for the system counter to reach a specific value — this makes precise timing very simple. We start by defining a timer variable and loading it with the number of counter ticks we want to wait. As the system timer is almost always running at 80,000,000 ticks per second, the delay time will usually be a significant number. Once we've loaded the variable with the delay, ticks synchronize it by adding the current value of the system counter.

```
starttimer    mov       loopTimer, us010
              add       loopTimer, cnt
```

Here we're loading the variable called *loopTimer* with the value stored in *us010*; this is a predefined value that you'll see at the end of the assembly listing.

```
us010         long      80000000 / 1000000 * 10
```

At first, this may seem odd because it looks like we're doing long division and multiplication in an assembly program. We're not. All PASM programs start as a **DAT** section in a Spin program and when launched with **cognew** are moved to the cog RAM. Since we started in Spin, the compiler will resolve this expression prior to

downloading the program.

We could, of course, have stated the value directly but here is a case for writing code that explains itself. In this case, we take the number of system counter ticks in one second and divide by one million to get the number of ticks in one microsecond. Now we multiply by 10 to get the number of ticks in 10 microseconds. This may at first seem like an arbitrary value, but it isn't. More on that later.

Let's drop into the main loop. Its purpose is to read the color setting from the hub RAM and then jump to the handler that sets the LED to that color.

```
ledloop         rdlong  color, colorAddr

setled          mov     tmp1, color
                max     tmp1, #3
                add     tmp1, #jmpcolor0
                jmp     tmp1

jmpcolor0       jmp     #ledoff
jmpcolor1       jmp     #ledgreen
jmpcolor2       jmp     #ledyellow
jmpcolor3       jmp     #ledred
```

The first part is easy with **rdlong**; this lets us read a value from the hub RAM into a cog variable. What follows is the equivalent of a PBASIC or SX/B **BRANCH** instruction. The color value is copied into *tmp1*. Now, *tmp1* should be something between zero and three, but as good programmers we don't take chances and will do a bit of error trapping; in this case, we limit the value of *tmp1* to three by using the **max** instruction.

And now for a little tricky stuff: We add the starting location (cog RAM) of a table of *jmp* instructions to the value of *tmp1* and then jump to the result. When *tmp1* is zero, we will end up jumping to **ledoff**; when *tmp1* is three, we will end up jumping to **ledred**. We could have used **cmp** (compare) and **if_e jmp** with each value, but this version of the code is a little cleaner, especially with long tables. Note that I've added extra labels to the table for clarity.

Okay, let's control the LED — it's nothing more that setting the direction of current flow (if any) through it.

```
ledoff          andn    outa, gMask
                andn    outa, rMask
                jmp     #loopwait

ledgreen        or      outa, gMask
                andn    outa, rMask
                jmp     #loopwait

ledyellow       add     rgCntr, #1
                cmp     rgCntr, #16     wc
       if_b     jmp     #ledgreen
                mov     rgCntr, #0

ledred          andn    outa, gMask
                or      outa, rMask

loopwait        waitcnt loopTimer, us010
                jmp     #ledloop
```

To turn an output pin off, we need to set its driver to zero and the **andn** (and not) instruction — when used with a mask — takes care of that for us. As I stated the last time, Propeller owes many of its features to the success of the BASIC Stamp and, believe it or not, the **&/** (and not) operator is part of PBASIC 1.0 — the language that runs on the original BASIC Stamp released in 1993!

The **andn** instruction actually does two things: it inverts the bits of the second value and then ANDs the two values together. The result is written back into the first value. So, we take a mask that has one bit set that represents the pin we want to affect. By inverting this mask, we now have a value that is all ones except for the bit that represents our pin — this bit is set to zero. By **and**-ing the outputs register (**outa**) with the inverted value, our pin is set to zero and all others are preserved. So, to turn off the LED we use **andn** to write zeroes to the green and red control bits in **outa**. With both pins set to the same level, no current flows and the LED is off. The code for green and red should be easy to follow: Turn one pin on and the other off — this falls right into the no-brainer basket. But what about yellow?

I stated earlier that we have to run the green side of the LED more cycles than the red to create a color that approximates yellow. With my LED, I found that 15 cycles of green to one cycle of red looked good. So, when we jump to **ledyellow** we're going to increment a cycle counter (*rgCntr*) and check to see if it has reached 16. While *rgCntr* is less than 16, we jump to the green handler; when *rgCntr* hits 16, we drop through, reset the counter, and then jump to the red handler.

Another thing we have to get used to when using the Propeller is that the C (carry) and Z (zero) flags are not automatically updated as with other controllers (e.g., SX). The upshot is that we can maintain the flags through other instructions and not have to worry about them being clobbered. The downside is, of course, that we have to remember to tell the assembler to enable them.

You'll see **wc** — called an effect — at the end of the **cmp** line in the yellow handler; this will write the carry flag based on the result of the compare. The compare instruction works very much like **sub** except that it doesn't affect the first value. When the first value is less than the second, the carry flag will be set (1).

Do yourself a favor and put one of those sticky flags on Table 5-2 in the Propeller manual; this table lists the aliases for the various combinations of C and Z flags that can be used to conditionally control instructions. One of the aliases for the carry flag being set is **if_b** which is short for IF BELOW. As you can see, we've applied this to the **jmp** that follows the compare to make it conditional. When the value of *rgCntr* is below 16, then we jump to

the green handler. Otherwise, we drop through, reset *rgCntr*, and then jump to the red handler. The end result is a modulated LED that appears yellow.

Finally, we drop into a **waitcnt** instruction that will cause the program to pause until the system counter matches the value in *loopTmr*. Another feature of **waitcnt** is that it can automatically reload the control variable — this makes using it to control loop timing very simple.

Alright, the driver is done so let's fold it into a Spin program. You'll find that most cog-based objects include methods called **start** and **stop**.

```
PUB start(p, c) : okay

  stop

  gPin := 0 #> p <# 26
  ledColor := LED_OFF #> c <# LED_RED

  okay := cog := cognew(@leddriver, @gPin) + 1

PUB stop

  if cog
    cogstop(cog~ - 1)
```

Note that the first thing the **start** method does is call **stop**. This is important because we don't want two cogs attached to the same object. The **stop** method checks to see if the LED driver is already running (*cog* will be non-zero) and terminates it if it is.

The **start** method expects two parameters: the pin number for the green anode and the initial color state of the LED. Note the use of the **#>** (minimum) and **<#** (maximum) operators in the assignments of *gPin* and *ledColor*, this ensures that we pass legal values to the driver. You may wonder why the green anode is limited to pin 26. My logic is this: Pins 31 and 30 are used for the serial connection to program the Propeller, and pins 29 and 28 connect to the EEPROM that stores the program — this leaves pins 27 and lower to use. We limit the green anode pin to 26 because the driver assumes that the red anode is the next pin up from the green pin. Finally, you can see that **cognew** is passing the address of *gPin*, not the value of *gPin*. This is critical because we need to know the address of the parameter(s) we're passing to the driver.

Before getting to the LED demo, let's round things out with methods that will make setting the LED color simple and virtually self-documenting.

```
PUB setcolor(c)

  ledColor := LED_OFF #> c <# LED_RED

PUB off

  ledColor := LED_OFF

PUB green

  ledColor := LED_GRN

PUB yellow

  ledColor := LED_YEL

PUB red

  ledColor := LED_RED
```

For just a little bit of typing – that I've already done for you! – we can have code that looks like this:

```
  myLed.setcolor(LED_GRN)
  myLed.red
```

You've certainly noticed the use of constants when setting the LED colors. A nice feature of Spin is that we can create a list of enumerated constants with a simple line, so the color constants declaration looks like this:

```
  #0, LED_OFF, LED_GRN, LED_YEL, LED_RED
```

Okay, then, let's put it to work:

```
PUB main | idx

  start(0, LED_OFF)

  repeat
    repeat idx from LED_OFF to LED_RED
      setcolor(idx)
      waitcnt(MS_001 * 500 + cnt)
    off
    waitcnt(MS_001 * 250 + cnt)
    green
    waitcnt(MS_001 * 250 + cnt)
    yellow
    waitcnt(MS_001 * 250 + cnt)
    red
    waitcnt(MS_001 * 250 + cnt)
```

The code in the **main** method launches the LED driver with the **start** method specifying pin 0 as the green anode and beginning with the LED off. The first **repeat** puts the code that follows into an infinite loop. At the top of that is a small loop that runs through the colors using the **setcolor** method to update the LED. After that, we use the individual color methods with 250 millisecond delays in between.

You'll find this code in ***jw_bicolor.spin***. (Downloads are available at **www.nutsvolts.com**.) This is just the starting point — what we want to do is separate the LED code so that we can use it in other projects. Open ***jw_bicolor_v1_demo.spin*** (LED demo code) and ***jw_bicolor_v1.spin*** (object methods and driver) to

see how I've separated the constituent parts. To use the driver as part of a project, we must declare it as an object.

```
OBJ

  led : "jw_bicolor_v1"

PUB main | idx

  led.start(0, led#LED_OFF)

  repeat
    repeat idx from {
      } led#LED_OFF to led#LED_RED
          led.setcolor(idx)
          waitcnt(MS_001 * 500 + cnt)

    led.off
    waitcnt(MS_001 * 250 + cnt)

    led.green
    waitcnt(MS_001 * 250 + cnt)

    led.yellow
    waitcnt(MS_001 * 250 + cnt)

    led.red
    waitcnt(MS_001 * 250 + cnt)
```

Notice how we've used the dot notation for object methods and how constants defined inside the object are used in the program. These changes are subtle and yet very important.

BLINK BABY, BLINK!

Okay, color control is nice but we're talking about an LED co-processor here, so let's rev it up! I envision having the need to set an LED to blink at a specific rate and it would be great if it could alternate between two colors of my choice (I consider off a color). Open the updated driver (***jw_bicolor_v2.spin***) and have a look at how we do this.

The first thing to do is add more control variables. We have two colors (one for each phase of the blinking) and two timing periods that control the blinking rate and duty cycle. And, don't worry, we can still have a solid color. All we have to do is set both phases to the same color and the LED will not blink.

Remember that 10 microsecond timing unit I selected earlier? Here's why I used that value: If we run a 10 microsecond loop one hundred times, it will consume one millisecond; a millisecond is a convenient unit of timing for delays (we're used to it from PBASIC and SX/B **PAUSE**). You know where this is going: The timing units for each phase will be specified in milliseconds.

```
getphases     rdlong  color0, color0Addr
              rdlong  time0, time0Addr
              rdlong  color1, color1Addr
              rdlong  time1, time1Addr
              add     phaseTimer, #1

runphase      tjnz    phase, #phase1

phase0        mov     color, color0
              cmp     phaseTimer, time0   wc
              jmp     #checkphase

phase1        mov     color, color1
              cmp     phaseTimer, time1   wc

checkphase
       if_ae  xor     phase, #1
       if_ae  mov     phaseTimer, #0
```

The top of the 1 ms loop is at **getphases** where we will read the current color and time settings for each phase. After reading the [new] settings, a timer for the current phase is incremented and we drop through to **runphase** which is the top of the 10 µs loop.

Since we only have two phases, we don't need a jump table as when selecting color, so the **tjnz** (test and jump if not zero) instruction works perfectly to get us to the phase handlers. Inside each handler, we move the phase color to the color control variable and then check the current phase timer against the time specified for that phase using the carry flag to record the result of the comparison. At **checkphase**, we check to see if the current phase time is above or equal to (**if_ae**) the phase setting and when that is true we flip the phase with **xor** (0 to 1, 1 to 0) and reset the time. This is a case that demonstrates the preservation of the carry flag and its use as a conditional controller with multiple instructions. Oh, and if you're wondering what happens when the condition fails ... the instruction is treated like a **nop** (it consumes four clock cycles but doesn't do anything).

The color control code doesn't change so let's address the end of the loop.

```
loopwait      waitcnt loopTimer, us010
              add     loopCntr, #1
              cmp     loopCntr, #100      wc
       if_b   jmp     #runphase
              mov     loopCntr, #0
              jmp     #getphases
```

This probably makes a lot of sense by now. After waiting for the 10 µs timer to expire, we're going to update a loop counter and compare it to 100 — again, 100 x 10 µs = 1 ms. When the loop counter is less than 100, we jump to the inner loop at **runphase**. Otherwise, we reset the counter and jump to the top of the outer loop at **getphases**.

IT'S BETTER TO FADE AWAY ...

Let's jump into the driver one more time and add a final feature: brightness control. As you'd expect, this is going to be accomplished with PWM (pulse width modulation) of the LED, but there is a catch: We're using a bi-color LED and current can be flowing in either direction (or alternating), so how do we modulate brightness? The answer is actually pretty simple: We modulate the direction control pin of one of the anodes. You see, if we make either anode control pin an input there will be no current flow — in any direction — through the LED.

Here's another reason why I went with a 10us inner loop: multiplying that by 100, we get a convenient one millisecond timing interval and we also have a counter to use for on-off control of the PWM cycle in 1% increments. Let's look at the code that gets inserted before the **loopwait** section (you'll find this in ***jw_bicolor_v3.spin***)

```
pwmctrl         test    level, level        wz
        if_z    andn    dira, gMask
        if_z    jmp     #loopwait
                cmp     loopCntr, level     wc
        if_b    or      dira, gMask
        if_ae   andn    dira, gMask
```

The top of the **pwmctrl** section first checks the value of *level* (brightness setting) for zero; when it is, we will turn off the output (by making the green pin an input) and skip right to **loopwait**. When level is something greater than zero, it is compared to *loopCntr* and when *loopCntr* is below the *level* setting we will turn the LED on. When *loopCntr* reaches *level*, the on-cycle is complete and we turn the LED off.

In the end, what we get is fixed-frequency, variable duty-cycle PWM that causes the LED to be on for the percentage set in *level*. So, what happens if we set *level* greater than 100? Nothing harmful; at 100 or higher, the LED will be on all the time as the value of *loopCntr* cycles between 0 and 99. I like this kind-of fixed-frequency PWM code because it's easy to configure. I recently used it in an RGB LED object and it worked really well.

Before I close, I want to tell you something about ***jw_bicolor_v3_demo2.spin***. This program shows how we can launch another cog to control the brightness of the LED object in the background; for example, to handle automated fades. The key here is having the LED object reveal the hub address of its brightness control variable. With this information, another object can manipulate brightness for advanced control. Check it out, it's pretty neat.

PROPELLER PLATFORM KITS!

Good news, gang! The response to the Propeller Platform was so positive (one Parallax forum member dubbed it "Propellerino") that my good friend, Ken Gracey, has agreed to make kits available through Parallax. This will certainly simplify building the P/P and save you money over having to buy raw PCBs yourself. **Figure 2** shows the final prototype; I really like the way it turned out. The only change from the original design is the regulators. We changed from the LM108x series to the LM29xx series to simplify parts procurement. My original thought for the high-current regulators was that I could use them for powering servos. Well, having worked with a lot of servo animatronics between the first version and now I found that this doesn't help and for big animatronics an external servo power supply is in order.

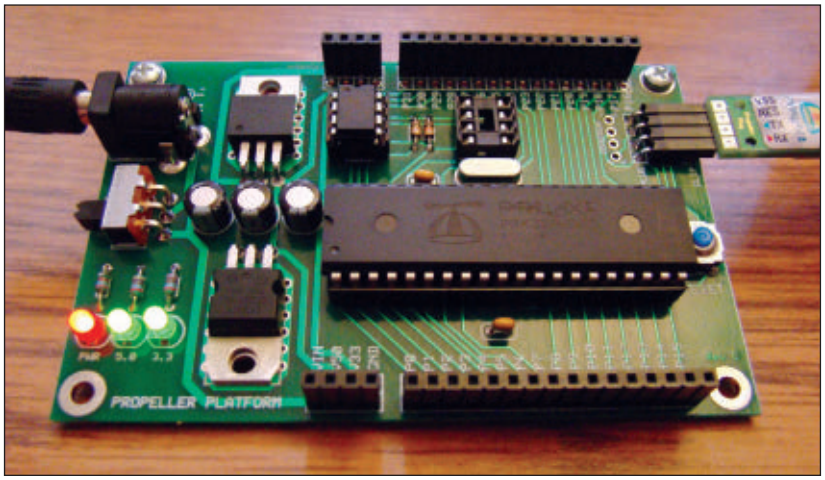
WRAP-UP

Okay, admit it ... when you first started reading this column you groaned, "Come on, Williams, LEDs again? Are you nuts?" Yeah, I get it, but I think I've shown that the lowly LED can become a thing of wonder with some cool code in the Propeller chip. I'm a big believer in learning new coding techniques with simple hardware and you can't get much simpler than an LED, right?

Okay, it's time to go experiment because we've laid the groundwork for a pretty serious project next time: Waldo Part Deux. Yep, the Waldo project from back in September 2007 was hugely popular, so for its two year anniversary we're going to recreate it for the Propeller and even add two more channels. The hardware will be a plug-in module for the Propeller platform that includes mini joysticks and all the support circuitry. In addition to the LED object we just created, we'll also create and use background ADC and servo control objects — it's going to be a lot of fun and a very cool project for use in your holiday animatronics displays.

Until next time, then, here's to spinning and winning with the Propeller. **NV**

■ FIGURE 2. Propeller Platform.



#12 SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

AVR Learning Platform Projects

Follow along with this series! Joe's book & kits are available in our webstore at **www.nutsvolts.com**

by Joe Pardue

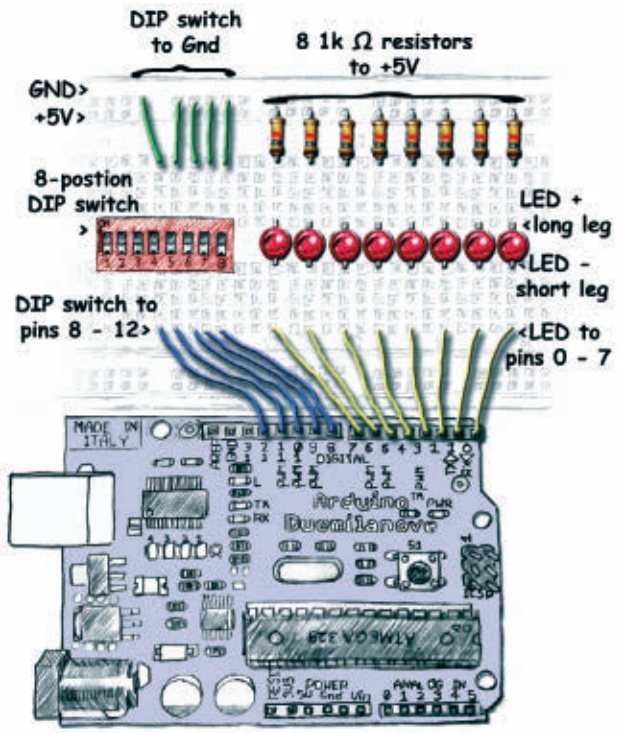
In this and the next few Workshops, we will continue with the ALP (AVR Learning Platform). We will take a look at some things that will quickly get us using more of the components from the Smiley Micros Arduino Projects kit (available from *Nuts & Volts* and Smiley Micros).

Recap

In Workshop 9, we began using a new development board — the Arduino Duemilanove — recognizing that *The Arduino Way* (TAW) is a very simple and easy way to begin using microcontrollers. We learned that while TAW uses a C-like language and has an easy-to-use IDE, it does not IMHO (In My Humble Opinion) provide a clear path to learning the C programming language or the details of the AVR architecture — both of which are our long-term goals for this Workshop series. To help overcome this, we learned how to convert TAW code to work with the more standard (IMHO) Atmel AVR tools: AVRStudio, WinAVR, and AVRDude using *A C Way* (ACW). We put together the ALP that uses the Arduino Projects Kit. This will provide our hardware development system for many Workshops to come.

This month, we will do another communications project, learn to read the voltage across a potentiometer, and then redo the Cylon Optometry code that we first did for the Butterfly back in Workshop 5 for the ALP.

■ FIGURE 1. Layout for Cylon Optometry.



The ASCIITable Example in TAW and ACW

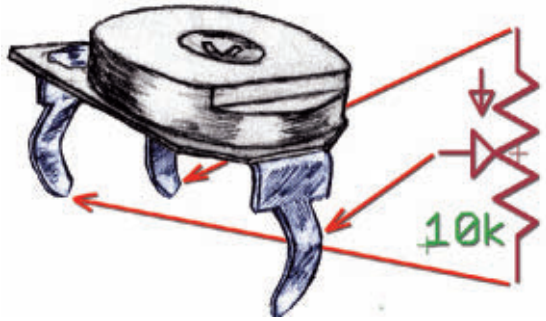
You can find the TAW version of the ASCIITable example in the Arduino IDE under the menu File\Sketchbook\Examples\Communication\ASCIITable. In the ACW version, we show TAW code commented out (marked with // to hide it from the compiler) to make it easier to compare the TAW and ACW versions. We will exercise the printf() function and learn that it doesn't have a binary formatter, so we do without that for now.

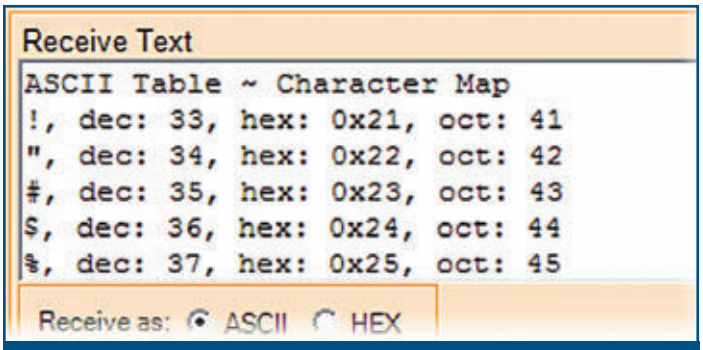
Be sure and review Workshops 9 and 10 on converting code from TAW to ACW. From those discussions, you should be able to get AVRStudio to find libACW001 and compile the following code:

```
// ASCII Table - ACW
// Joe Pardue April 10, 2009
// This program outputs an ASCII Table to
// a PC Terminal.

#include "libACW001.h"

int main(void)
```

```
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}


void setup()
{

  //Serial.begin(9600); //TAW
  serialBegin(9600);

  // prints title with ending line break
  // Serial.println("ASCII Table ~ Character
  // Map"); //TAW
  printf("ASCII Table ~ Character Map\n");

  // wait for the long string to be sent
  delay(100);

}

void loop()
{
  // prints value unaltered, first will be '!'
  //Serial.print(number, BYTE);
  printf("%c", number);

  // prints value as string in decimal (base 10)
  //Serial.print(", dec: ");
  //Serial.print(number);
  printf(", dec: %u",number);

  // prints value as string in hexadecimal
  // (base 16
  //Serial.print(", hex: ");
  //Serial.print(number, HEX);      )
  printf(", hex: 0x%x",number);

  // prints value as string in octal (base 8)
  //Serial.print(", oct: ");
  //Serial.print(number, OCT);
```

■ FIGURE 3. Potentiometer Schematic Symbol.



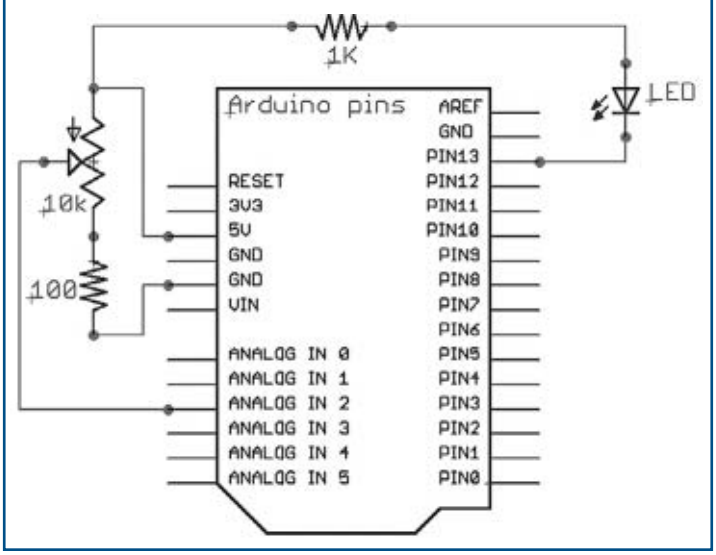


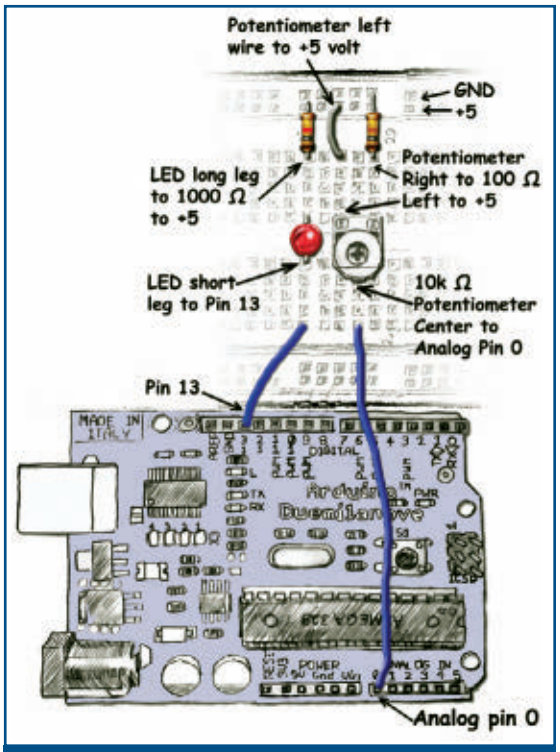
■ FIGURE 2. ASCII Table in Developer's Terminal.

```
  printf(", oct: %o",number);

   // also prints ending line break
   printf("\n");

  // if printed last visible character
  // '~' #126 ...

  if(number == 126) {
    // loop forever
    while(1){//true) {
      continue;
    }
  }
  // to the next character
  number++;

  // allow some time for the Serial data
  // to be sent
  delay(100);
}
```

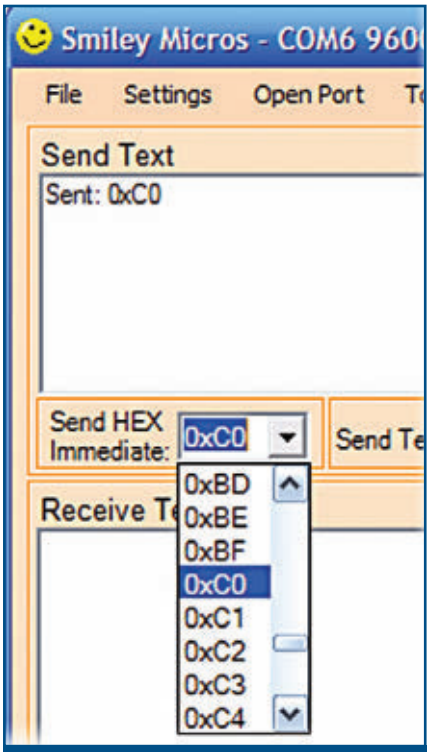
As discussed in earlier Workshops, compile this and upload it using the following two lines in the cmd window

■ FIGURE 4. Schematic for Potentiometer with LED.





■ FIGURE 5. ALP's AnalogInput layout.



■ FIGURE 6. Send HEX Immediate:.

to move it to the correct directory and run AVRDude:

Change directories with:

```
cd \ArduinoToAVRStudio-ASCII Table\default
```

Upload the code with:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:ASCIITable.hex
```

In the Developer's Terminal, I set the Receive Text window to the font Courier New/10 point so that the characters would align. You may also see that the terminal occasionally adds an extra blank line — a bug in the terminal I'll get to one of these days. Developer's Terminal was discussed in Smiley's Workshop 4: Teaching the Butterfly to Talk. You can download both the Developer's Terminal and that Workshop from either **www.nutsvolts.com** or **www.smileymicros.com**.

Analog Input: Reading a Potentiometer

Let's do a couple of projects with the Arduino Projects Kit potentiometer shown in **Figure 3**. The schematic for this project is shown in **Figure 4**. The layout using the breadboard on the ALP is shown as a drawing in **Figure 5**.

Note that in addition to the potentiometer, we have a 100 Ω resistor in this circuit that prevents us from shorting the power to ground if we set the potentiometer to zero Ω. The analog reading will be for five volts across a resistance for the potentiometer + the resistor from a maximum of 10100 Ω down to a minimum of 100 Ω. The AVR ADC will measure in 1,024 steps, with the 1,023 value for the full five volts. Since we have the 100 Ω resistor, our lowest ADC value should be about 1% of the full 1,024 range, or roughly 10. In my actual test, the low value was seven, but remember that both the pot and the resistor values have associated errors, so without some sort of external calibration, we will may be off a bit.

I recommend that first you test the hardware using the original AnalogInput from the Arduino IDE example code — the TAW version. BUT change the analog pin from 2 to 0 in the TAW code to match the hardware shown. It doesn't matter which analog pin you use as long as your code matches the hardware. Once you see that the hardware works — the LED blink rate varies as you turn the potentiometer to the left and right — you can move on to the slightly harder ACW source code version with reasonable confidence that the hardware is correct.

AnalogInput Example Ported from TAW to ACW

```
AnalogInput Example Ported from TAW to ACW

// AnalogInput
// mostly 'borrowed' from the Arduino example

#include "libACW001.h"

// select the input pin for the potentiometer
int potPin = 0;
// select the pin for the LED
int ledPin = 13;
// variable to store the value from the sensor
int val = 0;

int main(void)
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}

void setup()
{
```

```
  // declare the ledPin as an OUTPUT
  pinMode(ledPin, OUTPUT);
}

void loop()
{
  // read the value from the sensor
  val = analogRead(potPin);
  // turn the ledPin on
  digitalWrite(ledPin, HIGH);
  // stop the program for some time
  delay(val);
  // turn the ledPin off
  digitalWrite(ledPin, LOW);
  // stop the program for some time
  delay(val);
}
```

Change directories with:

```
cd \ArduinoToAVRStudio-AnalogInput\default
```

Upload the code with:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:AnalogInput.hex
```

Just as an aside, this was the first time I was actually able to copy code from TAW, change it to ACW, and have it compile, and upload with no errors. All the prior examples took some debugging. I tell you this so that you know that getting all this right isn't easy, even for the guy who is trying to teach it. Chant: 'Patience Persistence Payoff'.

The Dimmer Example in TAW and ACW

In Workshop 11, we saw how to send out serial data from the AVR to a terminal on the PC, but what about the other direction? In old-fashioned C, you'd use some version of the scanf() function to match the printf(), but we aren't going to do that. We will use some functions in libACW001.a that replace the TAW serial functions, as discussed in the last Workshop.

Again, I suggest that before you do this ACW you do it in TAW with the dimmer example from File/Sketchbook/Examples/Communication/Dimmer. The following is the ACW version with the original TAW functions commented out:

```
#include "libACW001.h"

// Use a pin with PWM
int ledPin = 9;

int main(void)
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}

void setup()
{
  // begin the serial communication
  //Serial.begin(9600);
  serialBegin(9600);
  pinMode(ledPin, OUTPUT);
}

void loop()
{
  byte val;

  // check if data has been sent
  // from the computer
  //if (Serial.available()) {
  if (serialAvailable()) {
    // read the most recent byte
    //val = Serial.read();
    val = serialRead();
    // set the brightness of the LED
    analogWrite(ledPin, val);
  }
}
```

Change directories with:

```
cd \ArduinoToAVRStudio-Dimmer\default
```

Upload code with:

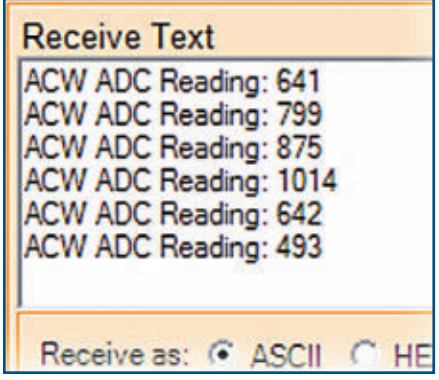
```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:Dimmer.hex
```

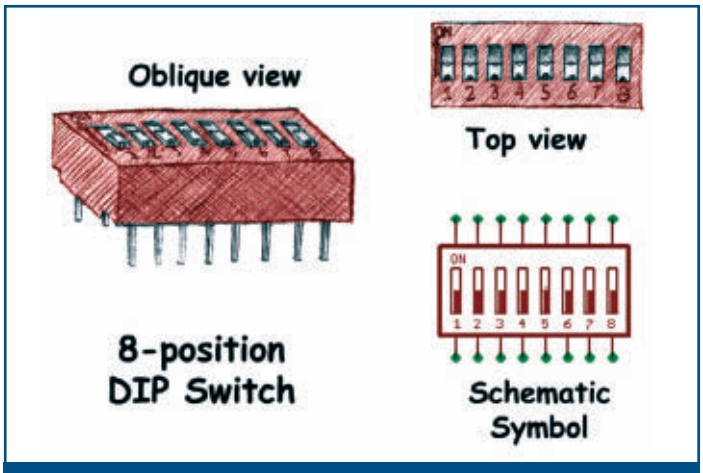
This program continuously checks to see if there is a byte of data available on the serial port and if so, uses that data to set the LED brightness. You can test it with Developer's Terminal (we saw how to use it in earlier Workshops). You can use the 'Send HEX Immediate:' as shown in **Figure 6**.

Read a Potentiometer with a Terminal

This project — ReadPot — isn't taken from an Arduino IDE example, but it is based on Tom Igoe's example shown in the Arduino Serial.print(data) web page. As usual, I leave in the TAW code commented out to show the TAW versus ACW differences. The output read by

FIGURE 7. ACW ReadPot Output.





■ FIGURE 8. DIP Switch Drawing and Schematic Symbol.

Developer's Terminal should look something like that shown in **Figure 7**.

ReadPot in ACW

```
// ReadPot ACW
// Joe Pardue March 24, 2009
// based on Tom Igoe's example in the
// Arduino Serial.print(data) documentation

#include "libACW001.h"

// variable to hold the analog input value
int analogValue = 0;

int main(void)
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}

void setup()
{
  // begin the serial communication
  //Serial.begin(9600);
  serialBegin(9600);
}

void loop()
{
  // read the analog input on pin 0
  analogValue = analogRead(0);

  // print prolog to value
  //Serial.print("ADC Reading: ");
  printf("ACW ADC Reading: ");

  // print as an ASCII-encoded decimal
  //Serial.print(analogValue, DEC);
  //Serial.println(); // print a newline
  printf("%d\n", analogValue);

  // delay 1 second before the next reading:
  delay(1000);
}
```

Change directories with:

```
cd \ALP ReadPot\default
```

Upload code with:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:ReadPot.hex
```

Cylon Optometry Redux

In Workshop 5, we used an eight-position DIP switch and eight LEDs to demonstrate some principles for using binary numbers in C with the Butterfly. We will do a subset of that project for the ALP. We are forced to use a subset since we can only read five DIP switches if we want to also use the eight LEDs with the Arduino board. We will sacrifice speed control from the original project that used four switches to encode 16 speeds; we will only use one switch for two speeds.

If this statement doesn't make sense to you — "There are exactly 10 types of people in the world. Those who understand binary and those who don't" — then please read Smiley's Workshop 5. You might also find this useful: Smiley's Workshop 5 Supplement 1 — Cylon Optometry.pdf. (Go to **www.nutsvolts.com**). The layout drawing for this project was shown at the beginning of the Workshop in Figure 1; the schematic follows in **Figure 9**.

Scroll Cylon Eyes

This time, we will show the code in both TAW and ACW since there is no example in the Arduino IDE or on its website.

Cylon Eyes TAW:

```
// CylonEyes TAW
// Joe Pardue April 11, 2009

void setup()
{
 // Init port pins
 DDRB = 0x00; // set port B for input
 DDRD = 0xFF; // set port D for output
}

void loop()
{
  for(int i = 1; i <= 128; i = i*2)
  {
    PORTD = ~i;
    delay(128);
  }
```

```
  for(int i = 128; i > 1; i -= i/2)
  {
    PORTD = ~i;
    delay(128);
  }
}
```

Cylon Eyes ACW:

For the ACW version, we drop the '~" thus changing the polarity of the LED scroll so we can tell the TAW and ACW versions apart.

```
// CylonEyes ACW
// Joe Pardue April 11, 2009

#include "libACW001.h"

int main(void)
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}

void setup()
{
 // Init port pins
 DDRB = 0x00; // set port B for input
 DDRD = 0xFF; // set port D for output
}

void loop()
{
  for(int i = 1; i <= 128; i = i*2)
  {
    PORTD = i;
    delay(128);
  }

  for(int i = 128; i > 1; i -= i/2)
  {
    PORTD = i;
    delay(128);
  }
}
```

Change directories with:

```
cd \ALP CylonEyes\default
```

Upload code with:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:CylonEyes.hex
```

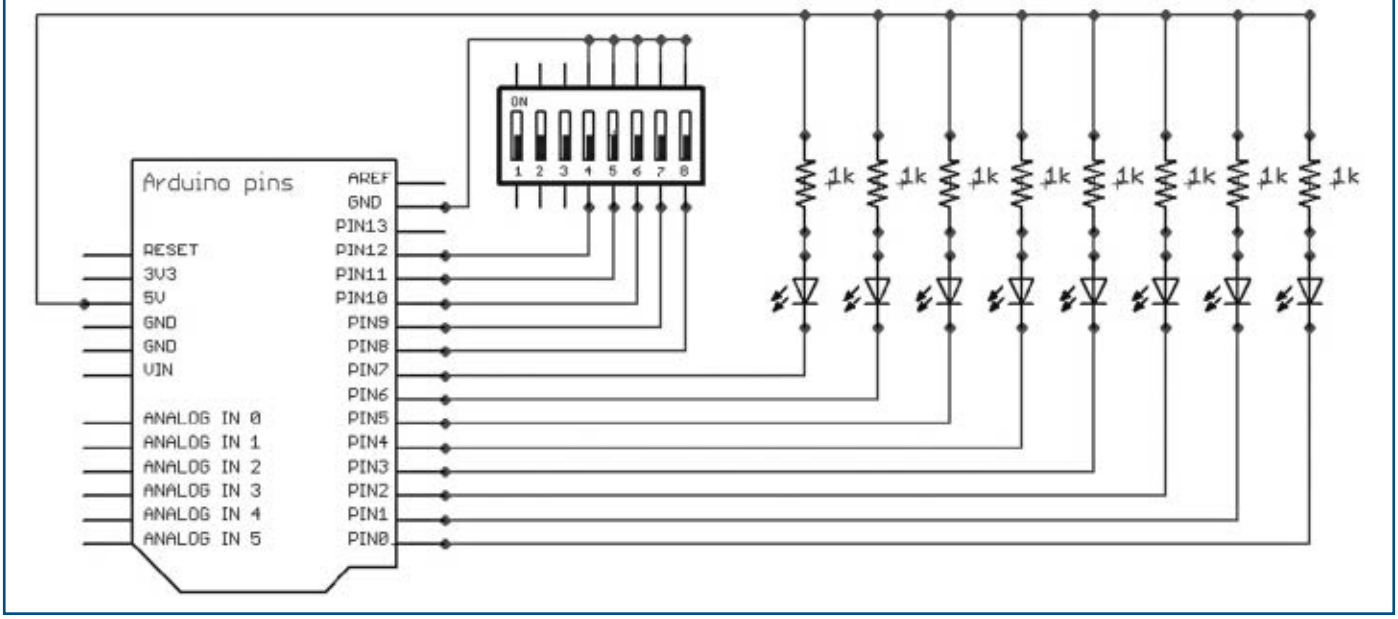
Show DIP Input on LED Output

Before we use the DIP switch to control our Cylon Eyes, let's make sure we can read its state and show that state on the LEDs.

DIPLEDTAW

```
// DIPLEDTAW
// Joe Pardue April 11, 2009

void setup()
{
 // Init port pins
```

■ FIGURE 9. Schematic for Cylon Optometry.



```
 DDRB = 0x00; // set port B for input
 PORTB = 0xFF; // set port B pullups

 DDRD = 0xFF; // set port D for output
}

void loop()
{
  PORTD = PINB;
}

DIPLEDACW

// DIPLEDTAW
// Joe Pardue April 11, 2009

#include "libACW001.h"

int main(void)
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}

void setup()
{
 // Init port pins

 DDRB = 0x00; // set port B for input
 PORTB = 0xFF; // set port B pullups

 DDRD = 0xFF; // set port D for output
}

void loop()
{
  PORTD = PINB;
}
```

Change directories with:

```
cd \ALP DIPLED\default
```

Upload code with:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:DIPLED.hex
```

Read DIP Switch Positions on Terminal

Now we have a little problem if we want to read the DIP input, show it on the LEDs, and send it out the serial port. The problem is that the lowest two PORTD pins that drive the rightmost two LEDs are also used to show traffic on the serial port. So, we use the shift operator (see Workshop 5) to move the five lower bits on the DIP switch left three positions so that they will be shown on the leftmost five LEDs.

DIPLEDSerialTAW

```
// DIPLEDSerialTAW
// Joe Pardue April 11, 2009

int value = 0;

void setup()
{
 // Init port pins
 DDRB = 0x00; // set port B for input
 PORTB = 0xFF; // set port B pullups
 DDRD = 0xFF; // set port D for output

 Serial.begin(9600);

}

void loop()
{
  // load PORTB pins into value
  value = PINB;

  // shift value left 3 positions
  PORTD = (value << 3);
  Serial.print("value = ");
  Serial.println(value);
  delay(1000);
}
```

DIPLEDSerialACW

```
// DIPLEDSerialACW
// Joe Pardue April 11, 2009

#include "libACW001.h"

int value = 0;

int main(void)
{
  init();  // Initialize private stuff
  setup(); // Setup the public stuff
  for (;;) loop(); // Call loop() forever;
  return 0; // You never get here.
}

void setup()
{
 // Init port pins
 DDRB = 0x00; // set port B for input
 PORTB = 0xFF; // set port B pullups
 DDRD = 0xFF; // set port D for output
```

```
 //Serial.begin(9600);
 serialBegin(9600);
}

void loop()
{
  // load PORTB pins into value
  value = PINB;

  // shift the value left 3 positions
  PORTD = (value << 3);
  //Serial.print("value = ");
  //Serial.println(value);
  printf("value = %d\n",value);
  delay(1000);
}
```

Change directories with:

```
cd \ALP DIPLEDSerial\default
```

Upload code with:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F -
U flash:w:DIPLEDSerial.hex
```

We have now shown all the components for the Cylon Optometry, but we've run out off space, so the final source code that provides the blink patterns is in the Workshop12 Sourcecode.zip file under /ACW/Cylon Optometry ACW/ and /TAW/Cylon Optometery TAW/. Remember, this is a repeat of some concepts from Workshop 5, so you may want to refer back to that if all this seems a bit rushed. **NV**

You can find the source code and supplements for this article in Workshop12.zip on the *Nuts & Volts* and Smiley Micros websites.

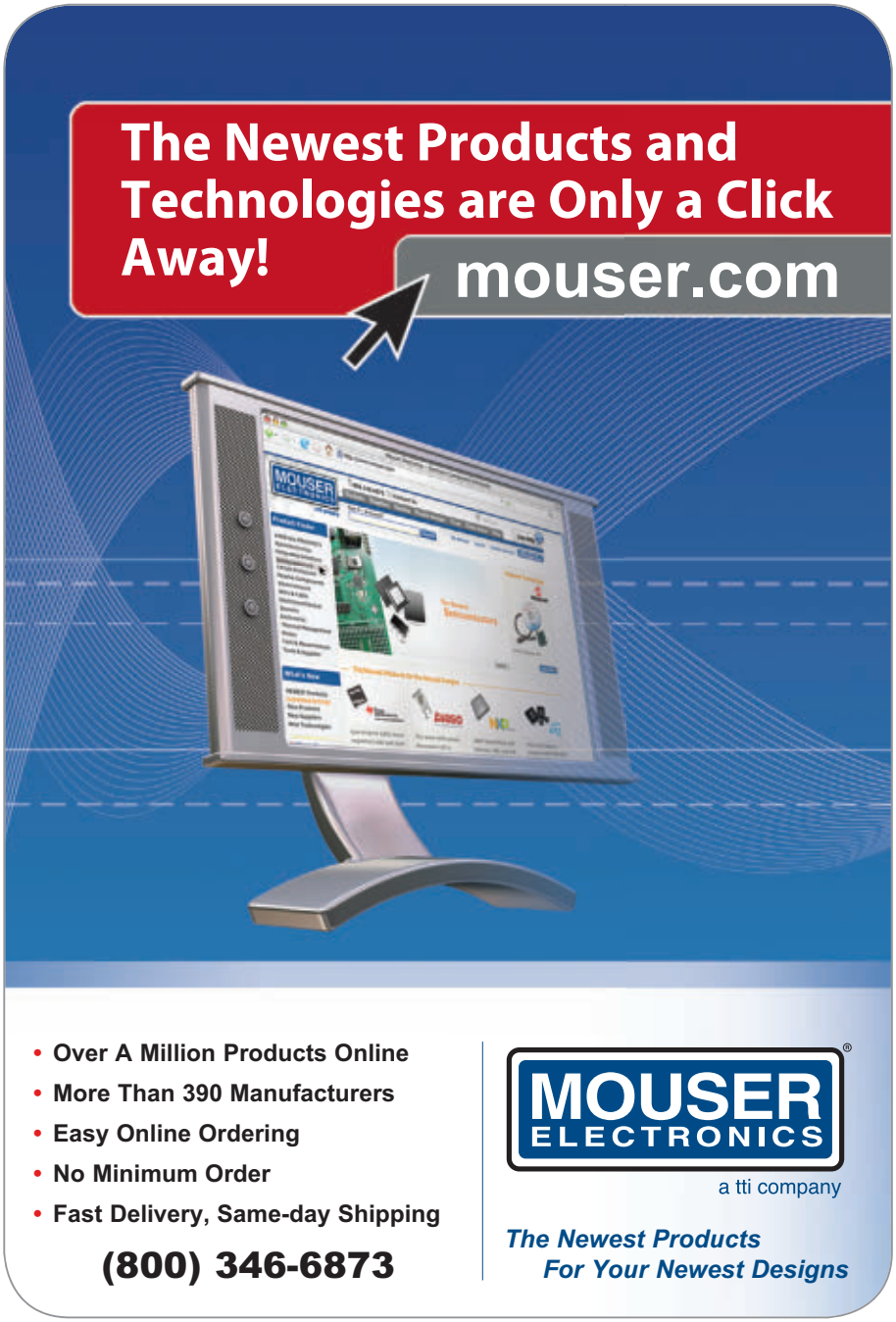
The Arduino Projects Kit

Smiley Micros and Nuts & Volts are selling a special kit: The Arduino Projects Kit providing components for use with Smiley's Workshops 9, 10, 11, and many future Workshops. Over time, we will learn simple ways to use these components, and more importantly we will use them to drill down into the deeper concepts of C programming, AVR microcontroller architecture, and embedded systems principles.

With the components in this kit you can:

- Blink eight LEDs (Cylon Eyes).
- Read a pushbutton and eight-bit DIP switch.
- Sense voltage, light, and temperature.
- Make music on a piezo element.
- Sense edges and gray levels.
- Optically isolate voltages.
- Fade an LED with PWM.
- Control motor speed.
- And more ...

One final note: The USB serial port on the Arduino uses the FTDI FT232R chip that was discussed in detail in the article "The Serial Port is Dead, Long Live the Serial Port' by yours truly in the June 2008 issue of *Nuts & Volts*. You can also get the book "Virtual Serial Programming Cookbook" (also by yours truly) and an associated projects kit from either *Nuts & Volts* or Smiley Micros.



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- ✔ Rock stable PLL synthesized exciter
- ✔ Front panel digital control and display of all parameters!
- ✔ Professional metal case
- ✔ Super audio quality!
- ✔ 25mW kit and 1W export models!

For nearly a decade we've been the leader in hobbyist FM radio transmitters. When it became time for a new model, we started from the ground up! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!

The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export-only market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC 110/220VAC plug in power supply. The stylish black anodized aluminum case measures 5.55"W x 6.45"D x 1.5"H. and is a great match to your other equipment. *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)*

FM30B	**Digital FM Stereo Transmitter Kit, 0-25mW**	**$199.95**
FM35BWT	**Export Only Transmitter Assembled, 1W**	**$299.95**

Professional FM Stereo Radio Station

- ✔ Built-in audio mixer!
- ✔ 2 line inputs, auto mic ducking!
- ✔ Dual LED bar graph meters
- ✔ Drift-free PLL synthesized operation
- ✔ Precision brick wall audio filter!
- ✔ 25mW kit and 1W export models!

The true professional workhorse of our FM Stereo transmitter line, the FM100B has become the transmitter of choice for both amateurs and professionals around the world. From the serious hobbyist to churches, drive-in theaters, colleges and schools, it continues to be the leader. Not just a transmitter, the FM100B is a fully functional radio station and provides everything but the audio input and antenna system.

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiters give your signal maximum "punch" while preventing overmodulation. Two sets of stereo line level inputs are provided with front panel level control for both. Dual front panel LED bargraph meters provide left and right channel audio level metering. In addition to the line level inputs, there is a separate microphone input with a built-in mic mixer to control the level. Not enough? How about unattended microphone ducking! When enabled, the presence of mic audio automatically reduces and overrides the line level input! Just like the professional units at a fraction of the cost. The FM100B is truly a complete radio station!
(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM100BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM100B	**Super-Pro FM Stereo Radio Station Kit, 5uW-25mW**	**$269.95**
FM100BEX	**High Power Version Kit, 5uW-1Watt Output**	**$349.95**
FM100BWT	**Export Only Transmitter, 5uW-1Watt, Assembled**	**$429.95**

Professional Synthesized Stereo FM Transmitter

- ✔ Fully synthesized 88-108 MHz for drift-free operation!
- ✔ Line level inputs and output!
- ✔ Simple DIP switch frequency setting

Priced like an inexpensive hobby transmitter but performs like a commercial unit! This unit is truly a cut above the rest, which probably explains why it is the most popular hobby transmitter around the world!

The FM25B features a PIC microprocessor for easy frequency programming without the need for lookup tables or complicated formulas! Frequency selection is done with simple DIP switches. The FM25B features a superb stereo generator providing you with amazingly good stereo separation to keep even the pickiest audiophile happy! Kit comes complete with case set, whip antenna, 120 VAC power adapter, & audio cable. SMT parts are factory preassembled! *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body)*

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	**$139.95**

Professional Synthesized AM Radio Transmitter

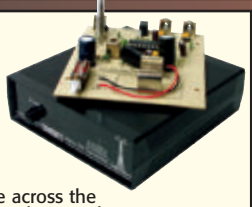
- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled
- ✔ Simple settings

Run your own professional sounding AM "Talk Radio" station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area.

It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. The PLL synthesized frequency is easily set with dip-switches and is rock solid without any drift, just like our FM25B. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!
(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body)

AM25	**Professional Synthesized AM Radio Transmitter Kit**	**$99.95**

Tunable FM Stereo Transmitter



- ✔ Tunable throughout the FM band, 88-108 MHz!
- ✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and is manually tunable across the entire band. The detailed manual covers theory, range, and FCC Rules & Regulations making it a favorite school and Scouting learning kit. Runs on an internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter. Learn all about FM stereo broadcasts with this simple kit. Includes matching case!

FM10C	**Tunable FM Stereo Transmitter Kit**	**$44.95**
AC125	**110VAC Power Supply for FM10C**	**$9.95**

Tunable AM Radio Transmitter

- ✔ Tunes the entire 550-1600 KHz AM band!
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Easy to assemble one evening kit!
- ✔ Line level input with RCA connector

A great first kit, and a really neat AM radio transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! Learn kit building and radio theory and at the same time get on the air with your own "station"! The AM1C has also been used by Scout camps, churches, schools, and other organizations to provide easy, low cost communications at events, meetings and much more. Includes matching case!

AM1C	**Tunable AM Radio Transmitter Kit**	**$34.95**
AC125	**110VAC Power Supply for AM1C**	**$9.95**

Tru-Match FM Broadcast Antenna

We've been besieged with calls asking us where to get a good quality FM Broadcast antenna. Remember, matching your antenna to your transmitter is the single most important link in your transmitter setup - and a good antenna and match are the secret to getting maximum range.

- ✔ Fully weatherproof-rugged PVC construction
- ✔ Matches 50 or 75 ohm systems
- ✔ Tunable for a perfect match over the entire 88-108 MHz FM band
- ✔ 25 watt RF power maximum

When we say "match" we mean electrical impedance match... if the proper impedances are not maintained between transmitter and antenna, power is reflected away from the antenna and back into the transmitter! This can cause the final amplifier stage to be damaged, not to mention spurious signals and lousy range. Don't forget, there are three important factors in your broadcast range: antenna, antenna, and antenna! With the Tru-Match you'll get the most from your FM Broadcaster!

TM100	**Tru-Match FM Broadcast Antenna Kit**	**$69.95**

The Hottest Items!
And Great Summer Projects

Audio/RF Signal Generator

- ✔ DDS and SMT technology!
- ✔ 0 Hz to 5 MHz at 0.1Hz resolution!
- ✔ 0 to 10V peak to peak output level
- ✔ Sine, Square, or Triangle waveform

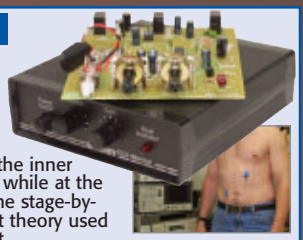
Following our world famous SG550, we are proud to introduce the SG560, the next generation signal generator!

To begin with we increased the frequency range all the way up to 5MHz and all the way down to 0Hz (yes, we mean zero...or DC!) in continuous 0.1Hz steps across the entire range! Then we gave it a variable output level all the way up to 10V peak to peak in either Sine, Square, or Triangle waveforms! You can also provide a DC offset to the output to recreate TTL, 4000 series logic levels, low voltage logic levels, AC waveforms with a DC component, or just plain AC signals!

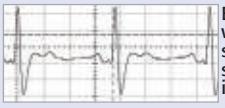
SMT and DDS technology is used throughout the SG560 for ultimate performance and reliability. If you're looking for a lab quality sig gen at a super hobbyist price, the brand new SG560 fits the bill...and a whole lot more!

SG560WT Audio/RF Signal Generator, Factory Assembled $329.95

Electrocardiogram Heart Monitor



- ✔ Visible & audible display of your heart rhythm
- ✔ Re-usable sensors included!
- ✔ Monitor output for your scope
- ✔ Simple & safe 9V battery operation



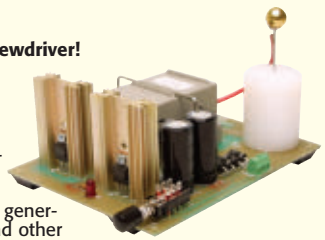
Enjoy learning about the inner workings of the heart while at the same time covering the stage-by-stage electronic circuit theory used in the kit to monitor it.

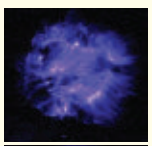
The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading every time! Multiple "beat" indicators include a bright front panel LED that flashes with each heart beat, an adjustable audio output to hear the beat, and of course, the monitor output to view on a scope, just like in the ER! Operates on a standard (and safe) 9VDC battery. Includes matching case for a great finished look. The ECG1 has become one of our most popular kits with hundreds and hundreds of customers wanting to get "Heart Smart"!

ECG1C	**Electrocardiogram Heart Monitor Kit With Case**	**$44.95**
ECG1WT	**Factory Assembled & Tested ECG1**	**$89.95**
ECGP10	**Replacement Reusable Probe Patches, 10 Pack**	**$7.95**

Plasma Generator

- ✔ Generates 2" sparks to a handheld screwdriver!
- ✔ Light fluorescent tubes without wires!
- ✔ Build your own plasma balls!
- ✔ Generate up to 25kV @ 20KHz from a solid state circuit!





This popular kit was conceived by one of our engineers who likes to play with things that can generate large, loud sparks, and other frightening devices! The result... the PG13 Plasma Generator designed to provide a startling display of high voltage!

It produces stunning lighting displays, drawing big sparks, to perform lots of high voltage experiments. In the picture, we took a regular clear "Decora" style light bulb and connected it to the PG13 - WOW! A storm of sparks, light tracers and plasma filled the bulb. Holding your hand on the bulb doesn't hurt a bit and you can control the discharge! It can also be used for powering other experiments; let your imagination be your guide! Operates on 16VAC/VDC for maximum output. Can also be run from 5-16VAC/VDC to reduce the output voltage.

PG13	**Plasma Generator Kit**	**$64.95**
PS21	**110VAC input, 16VAC output power supply**	**$19.95**

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- ✔ Monitor vehicle performance to save gas!
- ✔ Stores up to 300 hours of trip details!
- ✔ Records time, date, distance, speed, events and up to 4 separate engine parameters!
- ✔ Records extreme acceleration and braking!
- ✔ Automatic accident log, records the last 20 seconds before impact!
- ✔ View and reset engine diagnostic trouble codes!
- ✔ Test for preliminary emissions status!

Once again, no comments are necessary about the summer gas prices. Last summer they topped over $4 a gallon. Just look what's happened in the last 30 days leading into the summer of 2009 after what seemed like record lows all winter... Up $.49 in one month! And it's only going to get worse. At that price it's more important than ever to make sure your vehicle is in tip-top shape for the most economical performance possible.

Did you know old spark plugs can reduce fuel economy by 30%? It gets worse... a bad oxygen sensor cuts it by 40%! And that relates to a lot of extra gas and at 5 bucks a gallon, just do the math... That's a LOT of money!

With the CarChip Pro you'll have complete access to all your vehicles diagnostic data at your fingertips! Sort miles by type (business, personal or driver), set thresholds for alarms, calculate gas mileage, log extreme acceleration and braking, speed, engine parameters, and a whole lot more! And as you know, extreme acceleration does not equal fuel economy! Find out who's driving your vehicle like a race car...and deal with it!

The CarChip Pro is great if you have a new driver in the family. Easily monitor their performance and let them gain additional privileges with a good driving record! You have the proof! No more taking your car in to see why your "check engine" light is on. The CarChip Pro will automatically provide the trouble codes and allow you to reset it! CarChip Pro includes storage for up to 300 hours of driving data! If you're unfortunate enough to be involved in an accident, it even records all the vehicle's parameters for the last critical 20 seconds of operation! Includes USB cable, software and complete instructions.

8226 Davis OBDII CarChip Pro Data Logger $99.95

USB Experimenter's Interface Board

Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. You can also write custom Windows applications in Delphi VB, C++, or any other 32 bit Windows development tool that supports calls to a DLL. The mystery is solved with this kit!

K8055 USB Experimenters Kit $49.95

PIC Programmer & Experimenter

Not just a PIC programmer but a great test and experimenter's board to boot! Supports 8, 14, 18, and 28 pin PIC's. Create code in any ASCII word processor or Microchip's MPLAB development package and write it directly to the PIC. Separate sockets eliminate the need to patch a ZIF socket. Includes test and diagnostic software and a PIC16F627 Micro!

K8048 PIC Programmer & Experimenter Kit $34.95

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The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat! The PS provides 3, 4.5, 6, 7.5, 9, and 12VDC regulated outputs at 2A peak. Unclutter your bench today with the 3-In-1 Lab!

LAB1U 3-In-1 Multifunction Lab $129.95

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Voltage Conversion
- ✓ Understanding Thermal Lag
- ✓ Software-based Power Control

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

TIMER

Q I need your help. I am working with photocell and 555 timer circuits on a model train platform. I haven't been able to get the correct response from the circuits. What I need is when the train breaks the light beam, I need a relay to energize, and after the train passes and the photo cell detects light, I need a timer to time out and give me about two to 10 seconds before the relay de-energizes and returns to its original state.

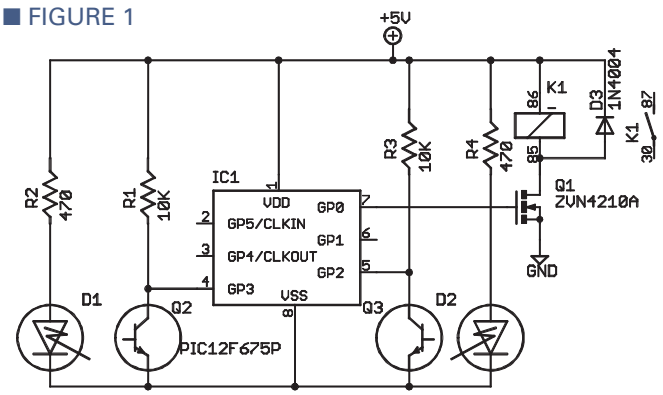
— John S. Mitterer

A The 555 timer is old technology; a microprocessor is the way to go nowadays. I don't know if this is a problem for you or not, but if the train stops such that the light is shining through the space between the cars, the system will assume it has passed and will de-energize the relay. Two photocells will avoid this problem, placed such that one is always blocked by a car. I have provided for this in the design; the circuit is **Figure 1** and the program is **Figure 2**.

The microprocessor is Mouser part number 579-PIC12F675-I/P and any logic level MOSFET can be used. I used ZVN4210A, Digi-Key part number ZVN4210A-ND. The infra-red radiator and detector are RadioShack 276-142.

The optical range was about six inches but could be increased by increasing the resistance of R1 and R3, but 100K doesn't work.

■ FIGURE 1




```
'* Version : 1.0
'* Notes   :There are two photo detectors; the output will be
'*         :high when the beam is broken.  When either beam is
'*         :broken, a relay is energized.  When both beams are
'*         :lighted, a two second time delay starts before the
'*         :relay is de-energized.
'*****************************************************
      REM DEVICE = 12F675
      CMCON = 7                 'SETS DIGITAL MODE
      ANSEL = 0                 'GPIO.0 TO 3 SET AS DIGITAL
      OPTION_REG = 0            'WEAK PULLUPS ENABLED
      TRISIO = %00001100        'GPIO.2 AND 3 AS INPUTS
      VRCON.7 = 0               'TURN OFF VREF

'*****************************************************
'CONDITIONS: INTERNAL OSC CLOCK OUT, WDT DISABLED,
' PWR UP TIMER ENABLED
'MCLR FUNCTION: INPUT PIN, BROWN OUT RESET DISABLED,
' NO CODE PROTECTION

START:
      IF NOT GPIO.2 AND NOT GPIO.3 THEN START
            'IF BOTH ARE LOW, THEN LOOP
      WHILE GPIO.2 OR GPIO.3
            HIGH GPIO.0         'ENERGIZE RELAY
      WEND

      IF NOT GPIO.2 AND NOT GPIO.3 THEN DELAY
      GOTO START

DELAY:
      PAUSE 2000                '2 SECONDS
      LOW GPIO.0                'DE-ENERGIZE RELAY
      GOTO START
END
```

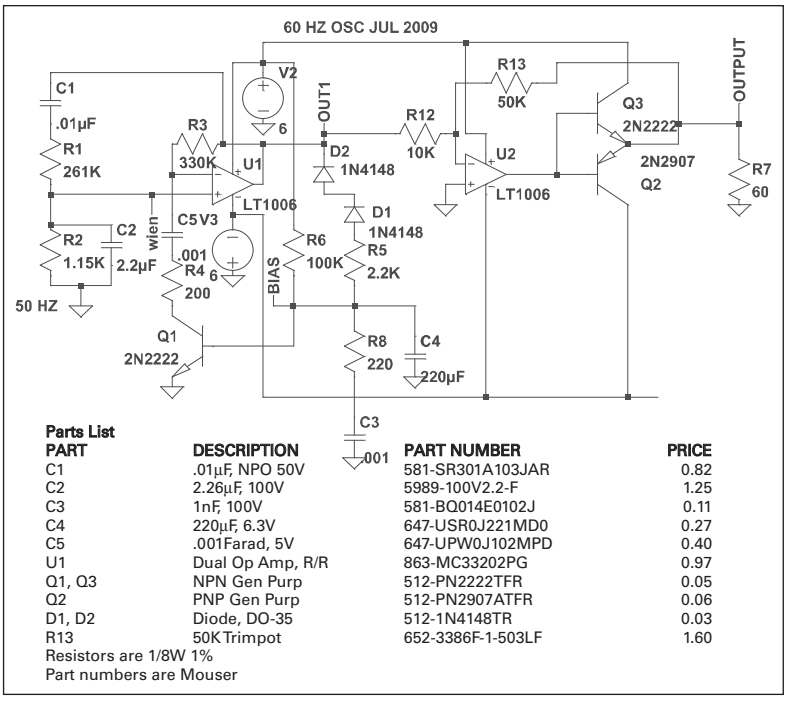
■ FIGURE 2

60 HZ GENERATOR

Q Do you have a simple circuit to produce a 60 Hz sine wave, near 12 volts P/P with a 100 mA load? The circuit will be powered by a 12 volt, 7 Ah battery.

— W. Thorp

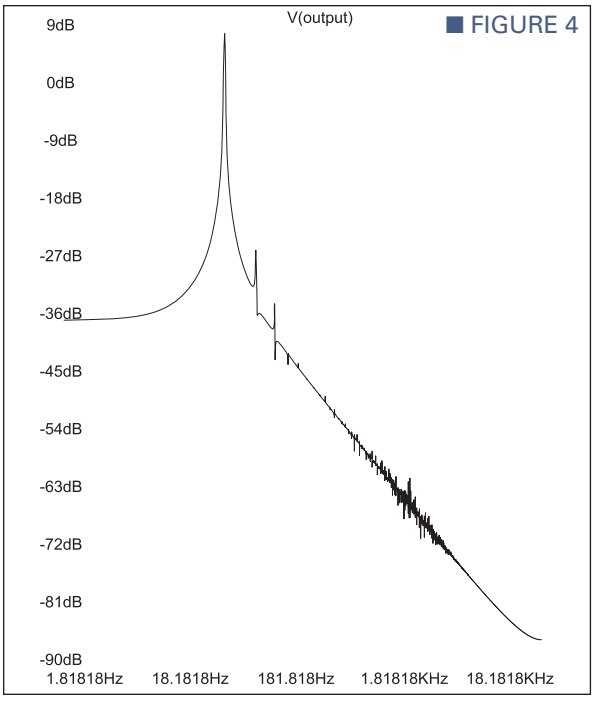
A The circuit in **Figure 3** is a Wien bridge oscillator. The two arms of the bridge are unequal to attenuate the



Parts List

PART	DESCRIPTION	PART NUMBER	PRICE
C1	.01µF, NPO 50V	581-SR301A103JAR	0.82
C2	2.26µF, 100V	5989-100V2.2-F	1.25
C3	1nF, 100V	581-BQ014E0102J	0.11
C4	220µF, 6.3V	647-USR0J221MD0	0.27
C5	.001Farad, 5V	647-UPW0J102MPD	0.40
U1	Dual Op Amp, R/R	863-MC33202PG	0.97
Q1, Q3	NPN Gen Purp	512-PN2222TFR	0.05
Q2	PNP Gen Purp	512-PN2907ATFR	0.06
D1, D2	Diode, DO-35	512-1N4148TR	0.03
R13	50K Trimpot	652-3386F-1-503LF	1.60

Resistors are 1/8W 1%
Part numbers are Mouser



■ FIGURE 4

signal because the "on" resistance of the transistor is very non-linear. The signal level at the op-amp input is several millivolts and the harmonic distortion is low. **Figure 4** is an analysis of the spectrum of the output (FFT) which indicates low harmonic content.

In Figure 3, R6 keeps Q1 turned on so that oscillation can start. The op-amp output tries to turn Q1 off through D1 and D2; C3 filters the feedback to maintain constant amplitude. R8 is necessary for stability. Without it, the feedback will overshoot and cut Q1 off completely. C4 bypasses high frequencies around R8 to improve the waveform. U2, Q2, and Q3 are a power amplifier to drive the load. In the **Parts List**, I made R13 a rheostat for amplitude control.

THERMAL FUSING VALUE

Q Regarding the datasheet of the STMicroelectronics 6A Trail BTA06; it shows a term called I^2T value for fusing.

What does this term mean and how is it to be used in circuit design?

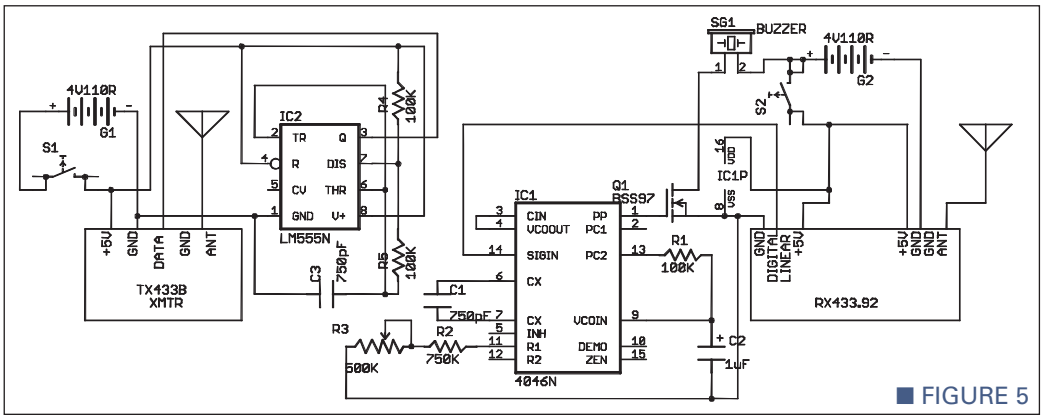
— Sam Zack

A This derives from the formula for power: $P=I^2R$. A wire or resistor can stand an overload for a short time due to thermal lag. This is the formula for fusing: $F=I^2T$ where F is the fusing rating and T is the time. If the rating is nine, the wire will fuse at three amps in one second or 9.5 amps in 0.1 seconds.

SMALL TRANSMITTER AND RECEIVER

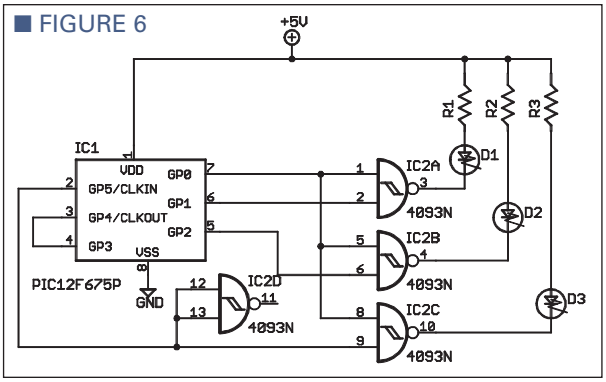
Q When my dog was a puppy, I had to use a Remote Trainer to keep him from getting in trouble. The Trainer had two functions: one was an Audible Tone; the other was a small Static Shock that was variable in strength. I hated to use the Static Shock even though I tested it on myself first and it does not really hurt, it just startles the dog. He is now a well behaved dog in most circumstances. The only problems I have are when he is off leash. For example, if someone nearby has food, he has to stick his nose in it to see if there is anything for him. I no longer have to use the Static Shock and the Audible Tone works like a charm to get him to behave, but I hate changing out his collars to use the Trainer.

I would like to build a small transmitter and mini receiver. The receiver needs to be very small and light weight so I can attach it to his collar when needed. It needs to be battery powered and last for up to eight to 10 hours. An inexpensive battery type would be helpful. The transmitter can be larger,



■ FIGURE 5

■ FIGURE 6



but small would be better. It needs a range of 100 to 200 feet (or longer if possible). The transmitter needs one function to activate an audible tone on the dog's collar with another louder tone as a second function for when he does not listen to the first one. I'd like it to be immune from outside interference if possible. Can you help me out with these two circuits?

— Jim Meng (Cypress, CA)

A Some years ago, Mouser carried a ceramic antenna for 433 MHz that was about two inches long. I was intrigued and bought two of them. I got a transmitter and receiver from QKits in Canada **www.qkits.com**; ($10 each) and found that the antenna worked very well. I used a reflector at the transmitter and got 1,000 feet range. Without the reflector, the range would be much less, probably 100 feet. The problem is that I don't know where to find that antenna; Mouser no longer lists it and the manufacturer (Yageo) does not even list antennas on its website. The bottom line is: You can purchase a helix antenna which is bulky, or just use a six inch piece of wire.

QKits has some newer transmitters and receivers; the 500 mW transmitter should have a lot more range than the 80 mW version I used. The online documentation is sparse; I don't know the pinout but labeled the pins as I think they will be. See **Figure 5** for the schematics. The transmitter and receiver are rated 4.5 to five volts, so should work with four AAA cells.

In order to have some interference rejection, I put a 555 timer running at 1 kHz feeding the data input of the transmitter. At the receiver, a 4046 PLL locks on to 1 kHz and the lock signal at pin 1 turns on a MOSFET to energize the buzzer. The buzzer is only 1/2 inch in diameter but it is loud; the dog won't like it. Any logic level MOSFET will work like the VN2222LL for example. The buzzer is Mouser part number 665-AI-1622WT5VR.

■ FIGURE 7

```
rem device 12F675
CMCON = 7               'SETS DIGITAL MODE
TRISIO = %00001000      'MAKES GPIO.3 AN INPUT
DEFINE OSCCAL_1K 1      'PRESERVES OSCILLATOR CALIBRATION
    START:
          LOW GPIO.4                'GPIO.4 OUTPUT IS CONNECTED TO
                                    'GPIO.3 INPUT
          GOSUB A
          GOSUB B
          GOSUB C                   'ADD AS MANY GOSUBS AS YOU WANT
          GOTO START

    A:
        WHILE NOT GPIO.3
        HIGH GPIO.1                 'TURN ON LED A
        GOSUB ROUTINE               'PWM LED A
        WEND                        'CONTINUE WITH NEXT INSTRUCTION
        LOW GPIO.1                  'TURN OFF LED A
        RETURN                      'NEXT GOSUB
    B:
        LOW GPIO.4                  'ESTABLISH THE CONDITION
        WHILE NOT GPIO.3
        HIGH GPIO.2
        GOSUB ROUTINE
        WEND
        LOW GPIO.2
        RETURN

    C:
        LOW GPIO.4
        WHILE NOT GPIO.3
        HIGH GPIO.5
        GOSUB ROUTINE
        WEND
        LOW GPIO.5
        RETURN

    ROUTINE:                'THIS WILL BE THE PWM ROUTINE
        HIGH GPIO.0
        PAUSE 20
        LOW GPIO.0
        PAUSE 20
        HIGH GPIO.0
        PAUSE 20
        LOW GPIO.0
        PAUSE 20
        HIGH GPIO.0
        PAUSE 20
        LOW GPIO.0
        HIGH GPIO.4         'FORCES THE PROGRAM TO THE NEXT GOSUB
        RETURN
        END
```

TRI-COLOR LED DRIVER

Q I have tried to come up with a simple method to cycle a tri-color LED through all possible color combinations. I used a small PIC to create a PWM in software to vary the LED brightness from full to off and back to bright again. So far, so good. I could not manage to implement three of them which also needed to run out of sync with each other in order to produce all possible combinations. Any suggestions?

— Bill van Dijk

A I am really a neophyte at PIC programming and I will no doubt get a lot of letters telling me there is an easier way to do it, but this is the way I would do it:

Your PWM signal is no doubt at a pre-selected port; connect that to one input of a two input AND or NAND gate. The other AND gate input will connect to port A. Do the same for ports B and C (see **Figure 6**). The program will be a series of GOSUBs:

GOSUB A
GOSUB B
GOSUB C
GOSUB B
GOSUB A
GOSUB C

And so forth, for all the combinations you want to implement. At the end put GOTO START if you want it to loop endlessly. Each of the subroutines will have the form:

A:
WHILE PORT D
HIGH PORT A
GOSUB PWM ROUTINE
WEND
RETURN

This is a brute force way but I don't know how to do it better. **Figure 7** is a program I wrote to test this idea.

DC-TO-DC CONVERTER

Q I am sure this question has been asked before but possibly there are better ways of doing it today. I would like to power a GPS receiver (12 VDC, 12W) from a 6 VDC source. This is so I can take it with me when I go touring in my 1954 Ford Meteor.

— Bill Blackburn

A I used National Semiconductor's Web Bench to design this converter (see **Figure 8**). The recommended IC was LM2587-12 which I found

MAILBAG

Dear Russell,

Re: December 2008 issue and the 60 volt, 13 amp supply question (page 24):

In the middle column, about two-thirds of the way down, the calculation for N: "Now using the formula N=..., I get less than one turn; use 15 turns so there is more than one turn on the secondary." How did you get from "less than one turn" to 15 and then, just next, "...20, that is a good number."?

— Sid Knox W7QJQ, Oklahoma

Response: I was sort of "thinking out loud." When the turns for 0.4 amps inductive current was less than one turn, and I knew that the secondary turns would be less, I took a guess as 15 turns for the primary. If the secondary turns had turned out to be less than one turn, I would have had to take another guess. But, I decided to check my guess using the catalog formula which gave a value of 20 turns for the primary. I checked that 20 turns would fit, so went with that. If it had not fit, I would have gone back to the 15 turn number.

I hope that explains how I got from here to there.

Dear Russell,

May I first just say how much I enjoy your column? I must admit to being somewhat in awe of your knowledge of the analog world. This is something I aspire to, but have never felt really great about for myself. I believe that your column is a good learning tool for me in that area. Your answers often inspire me to head to the workbench to try out the circuits you provide; now if I could just get it cleaned off enough to be able to do some work there!

I do have a bit of a quibble with your answer to the question titled "A Cycling Circuit" in the February 2009 issue. More specifically, it concerns the software listing in Figure 8. I should qualify this by saying that though I have written a lot of code for various microprocessors in a variety of languages, I have never written any at all for a PIC. Therefore, these comments are based solely on my theoretical understanding of the code, which could very well be wrong. I never trust myself totally on code that I have not executed and debugged!

Given the above disclaimer, it seems to me that the code will spend only a few microseconds each time around the loop in the line that reads "IF PORTB.3 = 0 THEN GOSUB HOLD". I also believe the vast majority of the time will be spent in the line that reads "PAUSE 30000". If that is correct, then I believe that pressing the Hold switch will result in freezing the display and thermocouple selection on the *next* rather than the desired *current* choice most of the time. My proposed fix is to simply move the "IF..." line to just after the "PAUSE..." line. With this change, I think the user will see a thermocouple of interest and press Hold sometime during the pause. When the pause is done, the code will then loop in the hold subroutine until the switch is released allowing viewing of that value as long as the user pleases. Please keep up the good work!

— Charlie Carothers

Response: You are so right! When I tested the program, I was not paying attention to which digit was held. Thanks for the feedback.

at Digi-Key, so I made the parts list (**Figure 9**) from their catalog.

Good layout procedure is essential in a switching power supply: Keep high current lines as short as possible and use a common point ground. C2 should be placed as close to the IC as practical. Use RTV to support the inductor. Put the circuit in a metal box to help keep noise of the switcher from interfering with the radio.

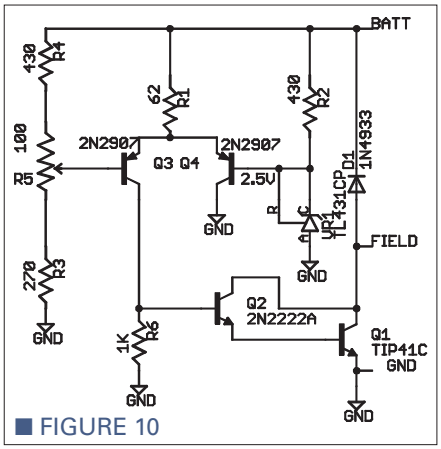
GENERATOR VOLTAGE REGULATOR

Q I have a request, if you can do it: a 1950+ tractor with a generator (alternator won't work because of mechanical space/mounting problems). Do you know of an electronic voltage regulator or have you ever made one for a generator? I have searched books and the web but other than finding several mechanical regulators, not had any luck.

— Bob H

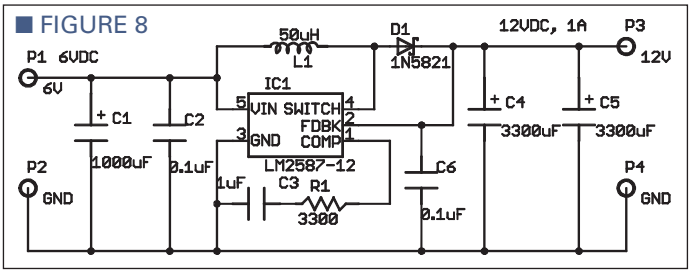
A I designed a generator regulator for my 1959 Lancia many years ago. I have updated it in **Figure 10**. The difference between an alternator regulator and a generator regulator is that the field of the alternator is grounded, so the regulator has to supply 12V (or 6V) to the field. The field of the generator is internally connected to the output, so the regulator has to connect it to ground.

In Figure 10, the TIP41 is a TO-220 power transistor which, in my experience, works okay without a heatsink. The TL431 is a 2.5 volt reference for one input of my simple op-amp. The 1N4933 is a fast diode to catch the backswing of the field inductance. It would probably not exceed the 100 volt rating of the TIP41C but why take a chance? Adjust R5 to maintain 6.8 volts at the battery. For a 12 volt regulator, R4 will be 1,300 ohms and I would double R1 and R2. **NV**



■ FIGURE 10

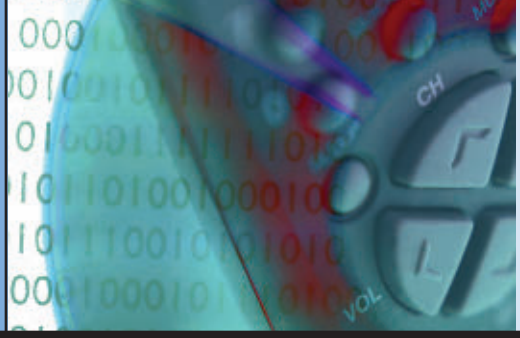
■ FIGURE 8



DC/DC CONVERTER PARTS LIST

■ FIGURE 9

PART	DESCRIPTION	PKG	PART NUMBER
C1	1000 µF, 10V, RADIAL	10MM	P12353-ND
C2, C6	0.1 µF, 50V, CERAMIC	CKO5	495-3349-ND
L1	50 µH, 9A, 0.012 OHMS	TOROID	M8717-ND
C3	1 µF, 50V, CERAMIC	CKO6	495-3393-ND
C4, C5	3300 µF, 16V, .02 OHMS	12.5MM	493-1536-ND
R1	3.3K, 5%, 1/4W	AXIAL	3.3KQBK-ND
IC1	LM2587-12	TO220-5	LM2587-12-ND



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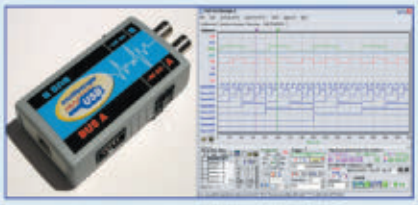

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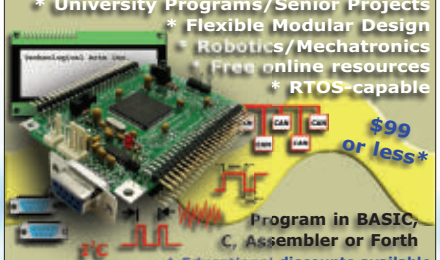

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THE ARCH-BALL CLOCK

BY ELZA SIMPSON

I love making unique clocks. I think the reason is because everybody knows what a clock is and when they come across a clock style they've never seen before their eyes light up and they want one. The clock presented here is one of my favorites.

The face of the clock consists of two upside down arches: one for hours and one for minutes. The hours arch is evenly marked out between 1 and 12. Likewise, the minutes arch is marked out between 0 and 60. Each arch has a steel ball bearing which is allowed to roll freely on the arch. The arches are rotated by stepper motors. As the angle of the arch changes, the ball bearing rolls to the lowest point, showing the current time. Of course, the most exciting time to watch — if watching time go by can be exciting — is when the time changes from 12:59 to 1:00 o'clock as both arches rapidly reverse direction.

Choosing the Motors

My first choice was to use R/C servo motors. These have been used to control R/C airplanes, cars, and boats for years, and more recently they've become very popular in robotics. I tried analog R/C servos but found there were dead spots in some of the positions displaying the time which caused the motor to jitter. I may not have had this problem if I used digital servos. However, since I didn't know that for sure (having never used a digital servo), I decided not to take the chance. Instead of spending $60 for two Futaba S3151 digital servos, I decided to spend $40 for two stepper motors which I knew would work. The $20 I saved on motors would more than pay for the extra circuitry required to drive the stepper motors vs. the servo motors.

The final reason I decided to use stepper motors is that they turn quietly. I have another clock which I spent a considerable amount of time and effort on, only to have it sit doing nothing. The reason is because the servo motors make too much noise when you're trying to fall asleep. (Music to my ears, but not so with other household members.)

Stepper Motor (Very) Basics

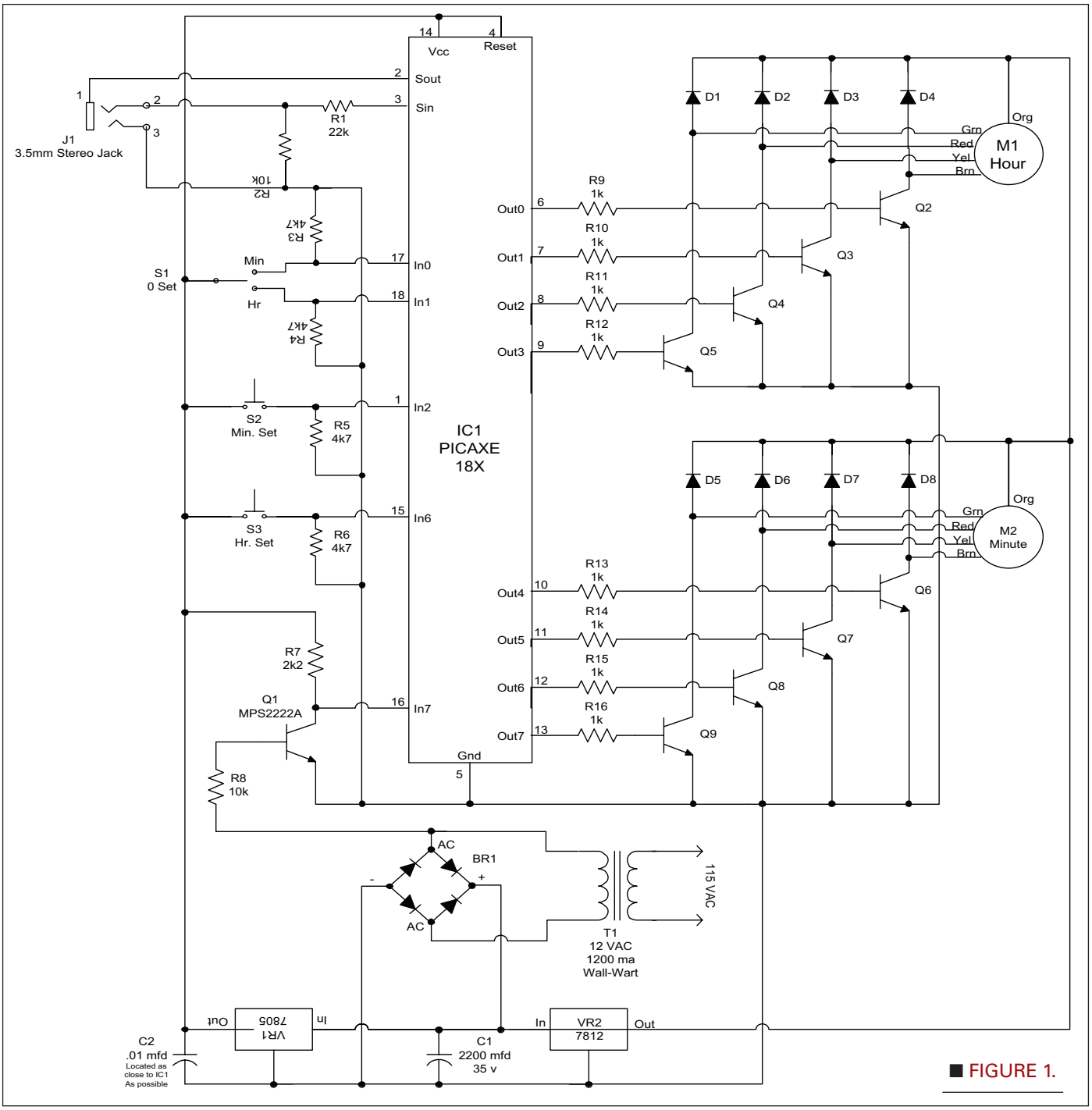
As the name implies, stepper motors turn in small steps. The step angle is measured in degrees, and motors come in a variety of step angles. For example, Jameco sells stepper motors with step angles of 0.9, 1.8, and 7.5 degrees. The one I used for this clock has a step angle of 1.8 degrees. This means that a single rotation of the motor's shaft takes 200 steps.

There are basically two categories of stepper motor: bipolar and unipolar. A simple bipolar stepper motor has two coils while unipolar stepper motors can have four individual coils, two center tapped coils, or two center tapped coils with the center taps tied together internally. To make the motor rotate, the coils are energized in a specific sequence. The difference in energizing the two types of motors is that the voltage polarity on the bipolar motor coils needs to be reversed while the polarity on unipolar stepper motor coils does not.

Another thing to consider when choosing a stepper motor is the holding torque. This is the amount of torque the motor has while standing still with the motor windings energized. The faster you energize the coils, the faster the motor turns. The faster the motor turns, the less torque you will have. One thing to remember when sequencing the motor's coils is that you must give the motor time to turn. If you sequence the coils too fast, the motor won't turn at all. Generally, the rpm of stepper motors is relatively slow. To reverse the motor's direction, you simply energize the coils in the reverse sequence.

The Circuit

Figure 1 shows the complete schematic for the clock. U1 is an 18X PICAXE microcontroller and is the brains of the clock. Programming the PICAXE is done through a



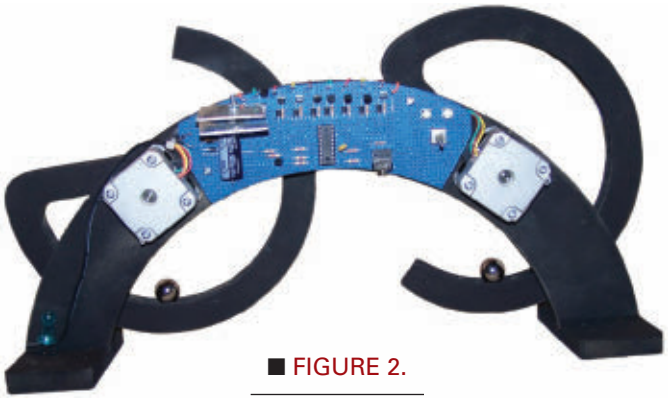
■ FIGURE 1.

serial cable connector between your computer and J1. (For more details, refer to the PICAXE Primer columns that run in the even months of *Nuts & Volts*.)

Since the 18X microcontroller doesn't have a crystal, we need an accurate way to supply a timing signal for the clock. This is done by Q1. The base of Q1 taps the 60 Hz AC coming from T1. At the collector is a TTL level (0–5 VDC), 60 Hz pulse. This pulse triggers an interrupt routine which counts the pulses; 3,600 pulses equal one minute.

Transistors Q2 through Q9 provide the required current and isolate the PICAXE from the 12 volts needed to drive the stepper motors. Diodes D1 through D8 protect the transistors from the reversing EMF of the motor's coils.

Switch S1 is an SPDT switch with a center off position. When in the off position, pushbuttons S2 and S3 are used to set the clock's time. When S1 is in the hour or minute position, S2 and S3 are used to "zero" the respective motor's position. When power is first applied, there is no way of knowing the position of the arches. "Zeroing" the stepper motors puts the arches in a known position. In actuality, only the minute arch is set to zero.



■ FIGURE 2.

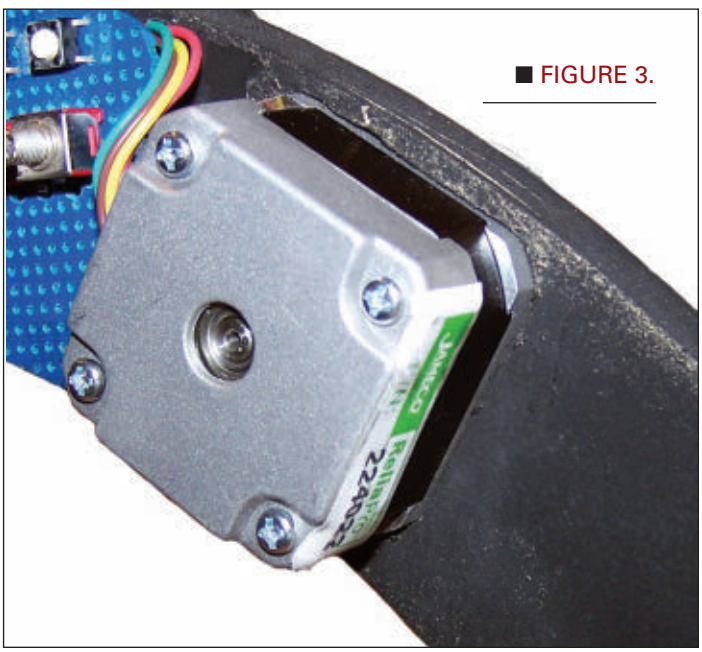
The hour arch is set to one. Only then can the time be set.

Almost any method can be used to build the circuit. I hand-wired the circuit on perf board (see **Figure 2**). For a single clock, I find this method to be faster than making a circuit board.

If you're going to make several clocks, then making a circuit board makes sense. No matter what method you choose, be sure to use a good heatsink on VR1 and VR2.

TABLE 1

Command	Function
V	Vout (raw 10-bit output)
I	Iout (raw 10-bit output)
U	Increment POT
D	Decrement POT
S	Status ("PPS READY" or "SHUTDOWN")
R	Reset
F	Firmware Revision



■ FIGURE 3.

Making the Arches

I drew the arch faces using a drawing program on my computer. However, there's no reason why you couldn't do it by hand using a compass and a protractor. I made the arches with an inside diameter of six inches, and the time marks are 18 degrees apart. I step the motors twice for each minute. Since each step of the motor is 1.8 degrees, this comes to 3.6 degrees for each minute. The markings are five minutes apart, or 18 degrees. I also made the time marks on the hour's arch 18 degrees apart. If you're not up to creating your own, you can download the full scale drawing from the *Nuts & Volts* website at **www.nutsvolts.com** or **http://picaxe.pertneer.com**.

Once you have the arch faces, use them as a pattern to lay out your wood. I used 1/2" medium density fiberboard (MDF). Cut outside the line and then sand to the line. It is very important that the inside arch where the ball bearing will be rolling on is smooth and without any nicks. Very carefully cut a groove down the inside of each arch. I used a router but you can also do it by hand using a sharp knife. This makes a track for the ball bearing to roll on. The bearing should roll on the outer edges of the groove, not inside the groove. Finally, paint the arches and glue on the faces. The hole for the motor shaft should allow for a tight, press-in fit.

The large arch that the servo motors and electronics are mounted to was also made from 1/2" MDF and has an inside diameter of 12 inches and an outside diameter of 15 inches. The pattern for this arch can also be downloaded. Two areas must be routed out for the servo motors to fit in. Although it is hard to see (because I got a really tight fit), **Figure 3** shows the routed-out area with the motor fitted into it. This allows the motor shafts to extend far enough out the front to mount the arches on.

Programming the PICAXE

The beauty of the PICAXE series of microcontrollers is that you don't need any special hardware — other than a cable — to program the chip. Plus, the programming editor is a free download from the Revolution Education website (**www.rev-ed.co.uk/picaxe**), and you can program it in BASIC.

The program code is available on the *Nuts & Volts* website. I'm not going to go through it line by line, however, I do want to point out a few items:

Timing for the clock is the 60 Hz pulse on the In7 pin. We want to catch and count each pulse. If the program is busy doing something else (like moving a motor), the pulse might be missed. To overcome this, line 31 sets In7 as an interrupt. When an interrupt is detected, all other program execution is halted and the interrupt routine is executed (lines 142-150). When the interrupt routine is finished, it returns program execution to where it was interrupted.

When power is first applied to the clock, there is no

way for the microcontroller to know the position of the motors. Before the time can be set, the user must "zero" the motors. Remember, the minutes are set to zero while the hours are set to one. This is done by lines 34-82. The user sets S1 to either minutes or hours, and presses buttons S2 and S3 to move the respective motor either forwards or backwards a single step at a time. Once this is done, S1 is moved to the center position, and S2 and S3 are used to set the time.

You'll notice that the same basic code is rewritten several times and you might be tempted to right subroutines. The problem with doing that is the PICAXE will get lost if the interrupt routine is called during the execution of the subroutine. Since the program only takes up a small portion of the available program memory, I wasn't too worried about creating subroutines.

The code:

```
For delayCount = 0 to delay
Next delayCount
```

It is a simple loop to slow down the pulses to the motors. This is done for two reasons. The first reason is to give the motors time to turn. Secondly, the motors used are relatively low torque and if they turn too fast they have a tendency to slip. You might be asking why I'm using the For/Next loop instead of using the Delay command. Good question. If the interrupt routine interrupts the Delay command, it will return program execution at the line immediately after the Delay command. The result is that the Delay command has no effect.

Setting the Time

Setting the time is a four step process. Steps 1 and 2 zero the motors while Steps 3 and 4 actually set the current time.

Step 1: Flip S1 to the hour position. Press S2 and S3 to position the hour arch so the ball bearing is sitting at the "1" position.

Step 2: Flip S1 to the minute position. Press S2 and S3 to position the minute arch so the ball bearing is sitting at the "0" position.

Step 3: Flip S1 to the center position. Press S2 to set the hour position to the current time.

Step 4: Press S3 to set the minute position to the current time.

The custom shaped PCB & programmed MCU for this project can be purchased from the *Nuts & Volts* Webstore @ www.nutsvolts.com or call our order desk, 800 783-4624.

PARTS LIST

ITEM	SUPPLIER/PART NUMBER
❑ IC1	PICAXE 18X microcontroller
❑ R1	22K, 1/4 watt resistor
❑ R2, R8	10K, 1/4 watt resistor
❑ R3-R6	4.7K, 1/4 watt resistor
❑ R7	2.2K, 1/4 watt resistor
❑ R9-R16	1K, 1/4 watt resistor
❑ C1	2,200 µF, 35 volt electrolytic capacitor
❑ C2	.01 µF disc capacitor
❑ D1-D8	1N4001 diode
❑ BR1	1.5 amp bride rectifier
❑ Q1-Q9	MPS2222A transistor
❑ VR1	7805, 5 volt, 1.5 amp voltage regulator
❑ VR2	7812, 12 volt, 1.5 amp voltage regulator
❑ J1	3.5 mm stereo jack
❑ S1	SPST, On-Off-On miniature switch
❑ S2, S3	N.O. pushbutton
❑ M1-M2	Unipolar stepper motor

Time to Wrap Up

It's easy to experiment with PICAXE microcontrollers and create unique items. I hope you find time to come up with your own unique applications. **NV**

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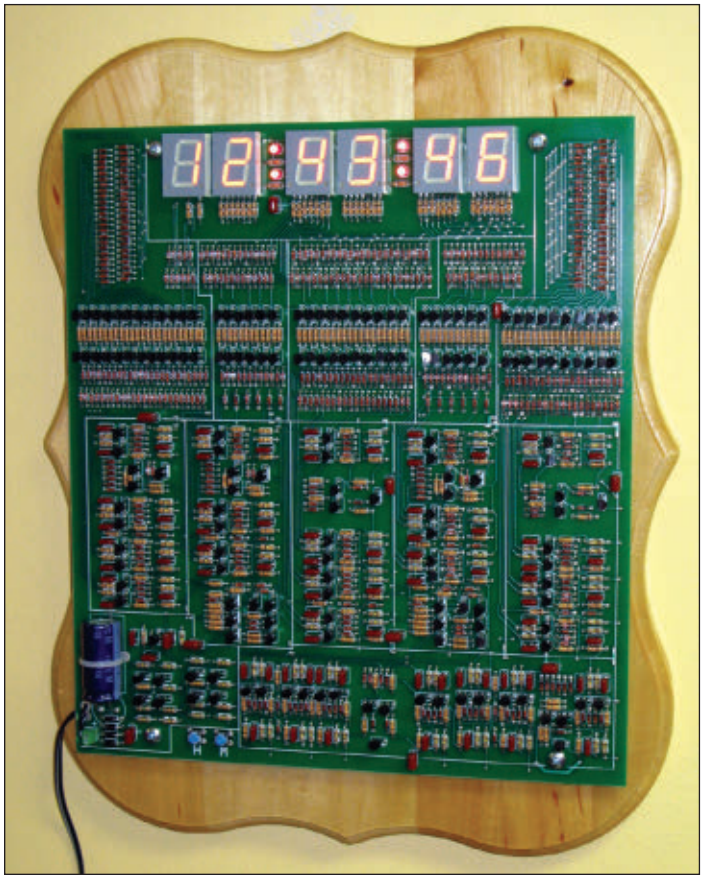
TRANSISTOR CLOCK

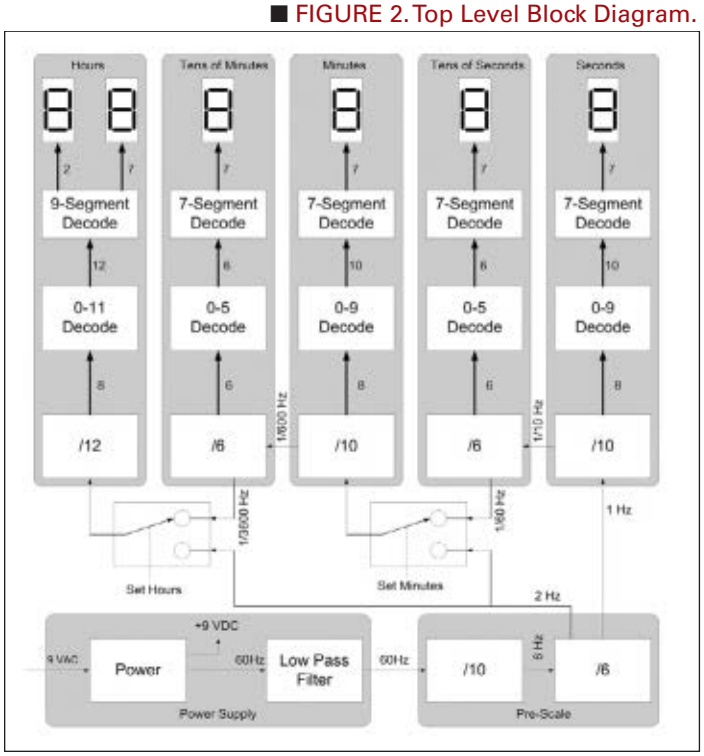
After decades of seeing projects and circuits using ever increasingly complex integrated circuits, I yearn for simpler times. As a teenager, I built fascinating and wondrous circuits using just a few transistors. My flashlight controlled relay could control a buzzer; music from my cassette tape player played on my radio with a two transistor circuit; my amplifier could drive a speaker. These circuits were from dusty hobby books found at my local library with names like "29 transistor circuits" or "electronic hobby circuits."

BY KEITH BAYERN

■ FIGURE 1. Transistor Clock.



■ FIGURE 2. Top Level Block Diagram.



Transistor Clock

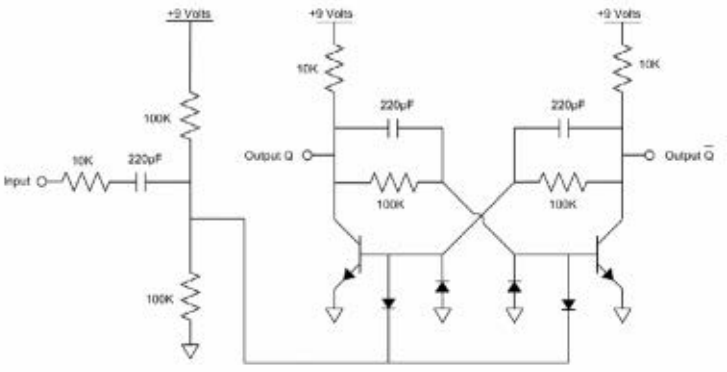
To return to those glory days, I decided to build a digital clock using only transistors as the active elements. After a few years of "work" (it felt more like play), the final parts count is 194 transistors, 566 diodes, 400 resistors, and 87 capacitors. Check it out in **Figure 1**.

This article will explain the circuitry at both the logic level and the transistor level. Time to get started ...

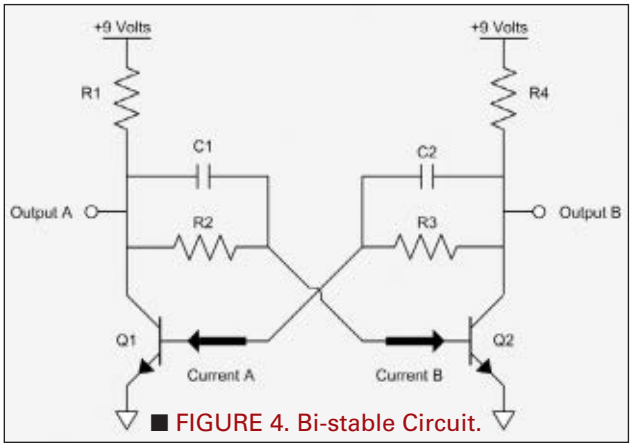
The Big Picture

Figure 2 shows the design at the functional block level. The power supply (lower left) rectifies and filters the incoming nine volts AC, converting it to nine volts DC to operate the circuitry and a 60 Hz clock. Next, a prescaler divides the 60 Hz by 10 and six, resulting in a 1 Hz clock. A 2 Hz clock is also routed to the time setting switches.

The 1 Hz — which is also a one second per pulse clock — drives a divide-by-10 counter who's output is 10 seconds per pulse. The four bits of the counter are decoded into a one-of-10 signal that drives a seven-



■ FIGURE 3. Toggle Flip-Flop.



■ FIGURE 4. Bi-stable Circuit.

segment display showing seconds. The high bit of this counter drives the next counter in the chain: a divide-by-six counter showing tens-of-seconds. Following that is another pair of counters: ÷6 and ÷10, showing minutes and tens-of-minutes. A divide-by-12 counter completes the clock by showing hours.

Flip-Flops

The heart of this clock is the two transistor toggle flip-flop shown in **Figure 3**. The bi-stable circuit in **Figure 4** will be used to explain the operation of the toggle flip-flop.

Assume that transistor Q1 is in the off state. The collector of Q1 is high impedance so Output A is pulled high by R1. A current flows through R2 (current B) into the base of Q2 switching Q2 "on" so Q2 conducts and pulls output B to ground. No current flows through R3 (current A) so Q1 is off (which is the initial assumed state). This is one of two stable conditions. The other stable condition is Q1 on and Q2 off. Note that they both cannot be on and they both cannot be off.

It's Toggle Time!

Assume the previous condition with Q1 off and Q2 on. Output A is high; current B is flowing into the base of Q2 so Q2 is on and output B is low. Imagine that current B is somehow interrupted for a moment. Q2 will turn off, output B will start to be pulled high by R4, and current A will start to flow through R3 and C2. Q1 will tune on, pulling output A low. The flip-flop has "flipped" to the other state. In other words, it has "toggled."

Consider Figure 3 again. The two diodes connecting bases to the input allow a short negative-going pulse to "steal" the base current for a moment on the falling edge of the input, causing the flip-flop to toggle.

Counters

The clock is made of a collection of counters. Counters made by a chain of n flip-flops result in binary ripple counters capable of dividing by 2n. A four flip-flop counter naturally counts from 0 to 15. To make it count from 0 to 9, it needs some steering logic on the flip-flop toggle inputs. **Figure 5** shows four flip-flops, the logic, and the internal clocks driving each flip-flop to make a divide-by-10 counter.

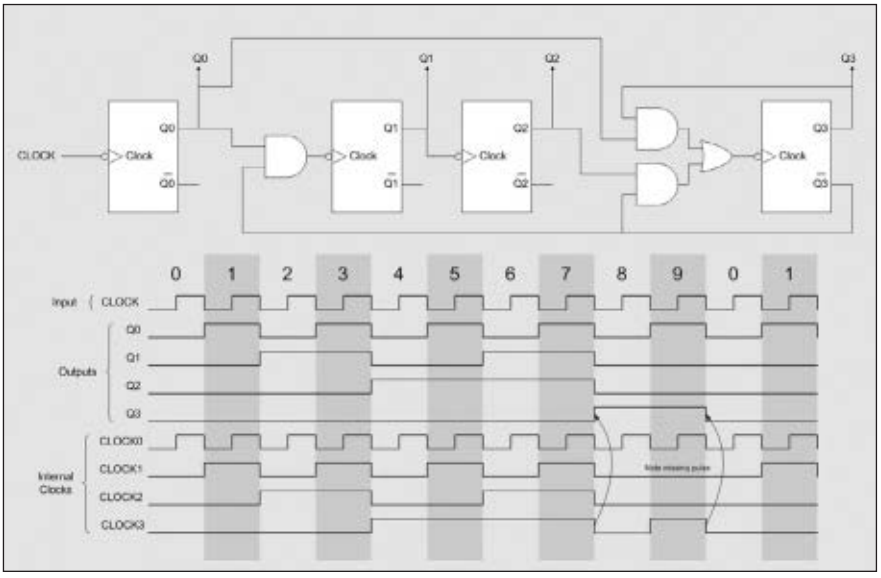
Note that at count 9, the clock to the second flip-flop is masked by the logic causing state 9 to transition to state 0, rather than state 10. One weakness of this approach is that if the counter powers up into a state higher than 9, it takes a few counts to get back on track.

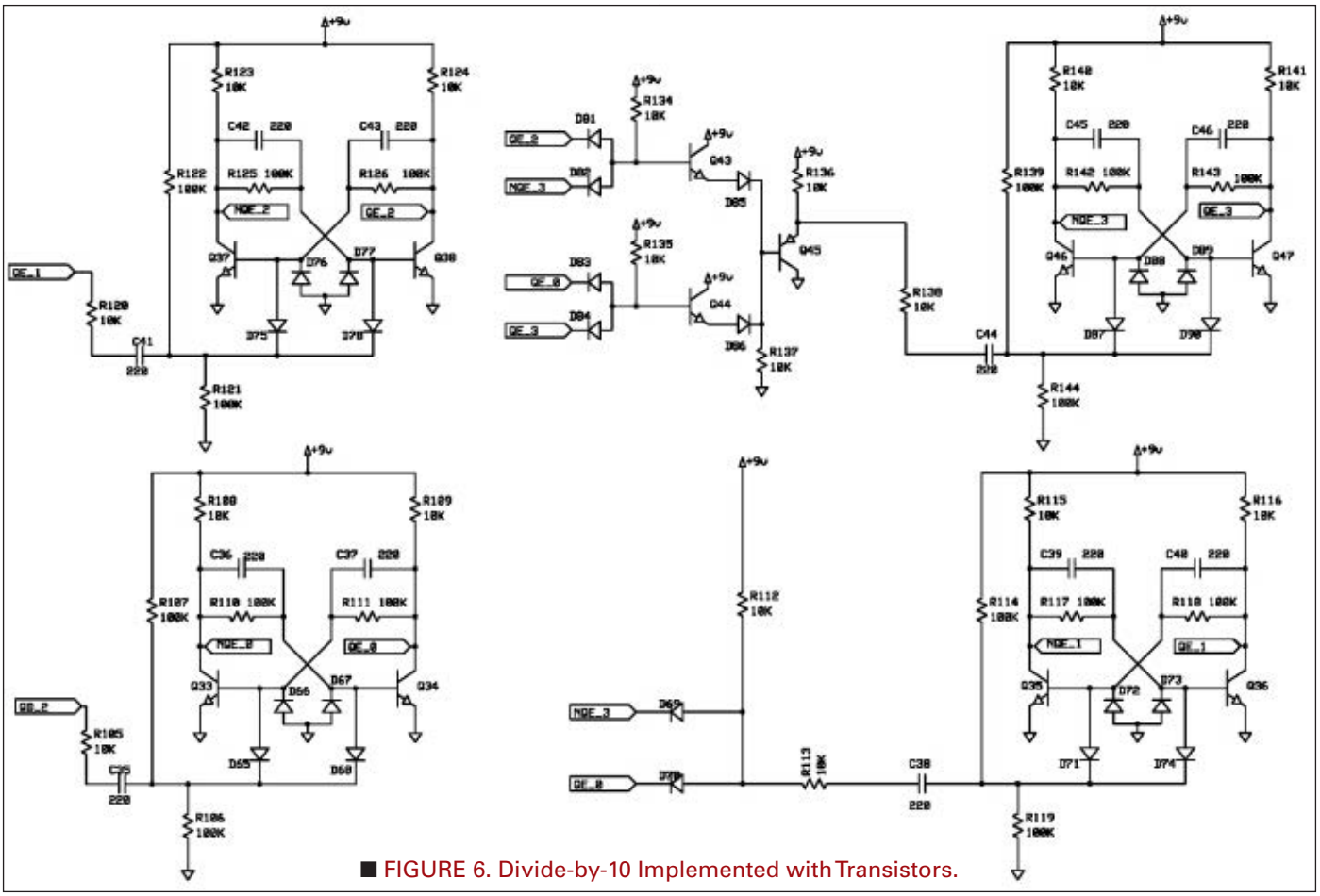
Figure 6 is a divide-by-10 counter transistor schematic of the logic circuit; note the two diode OR gate and the three transistor AND-OR gate.

Decoders

The output of the counters is decoded into one-of-n,

■ FIGURE 5. Divide-by-10 Logic.





■ FIGURE 6. Divide-by-10 Implemented with Transistors.

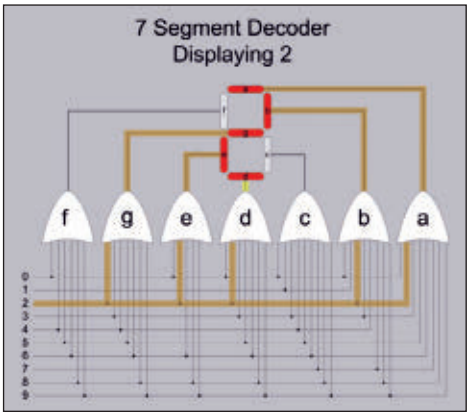
meaning the divide-by-six counter drives one of six lines; the decade counter drives one of 10 lines; and the hours counter drives one of 12 lines. For each numeric display, the decoded lines drive a diode array that implements a wired OR function. **Figures 7** and **8** show the seven-segment decoder in action.

60 Hz Extraction

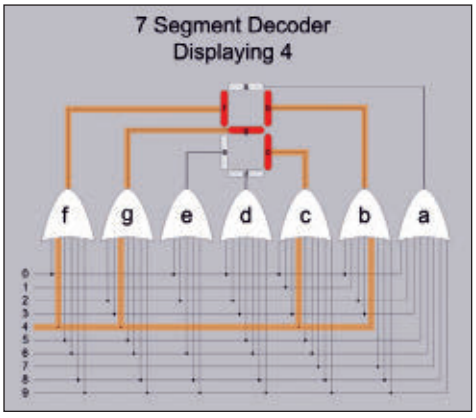
This clock uses the 60 Hz signal from the power company as a time base. Unfortunately, the power signal has spikes on it from equipment switching on and off, and these spikes can trigger the counters and falsely advance the time if allowed to propagate to the counters. Previous attempts to place an analog RC low pass filter on the 60 Hz did not prevent all power spikes from erroneously advancing the time. I devised a "brick wall" low pass filter with a cutoff at about 100 Hz. The logic is shown in **Figure 9** and the transistor implantation is in **Figure 10**.

In short, the 60 Hz sine wave is squared up, a pulse is developed from one edge, the pulse discharges a capacitor which charges up at a calculated rate, and the capacitor voltage is level compared to produce 60 Hz. The point of all this complicated rigmarole is that when a noise spike causes an extra pulse, it merely discharges the capacitor and causes a delayed edge on the output of 60 Hz so that the noise affects the duty cycle, not the frequency. It would be possible that a long noise burst could remove one cycle, but that rare likelihood has the almost unnoticeable effect of losing 1/60th of a second. The transistor implantation in Figure 10 shows two four-

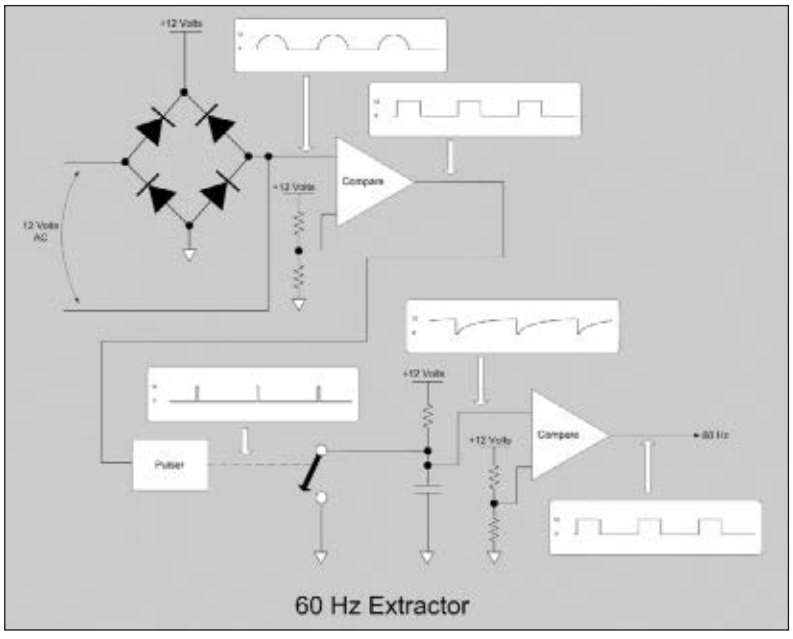
■ FIGURE 7. Seven-Segment Decoder.



■ FIGURE 8. Seven-Segment Decoder.



■ FIGURE 9. 60 Hz Extraction Logic.



transistor comparators with hysteresis and the pulsardischarger circuit.

Building the Clock

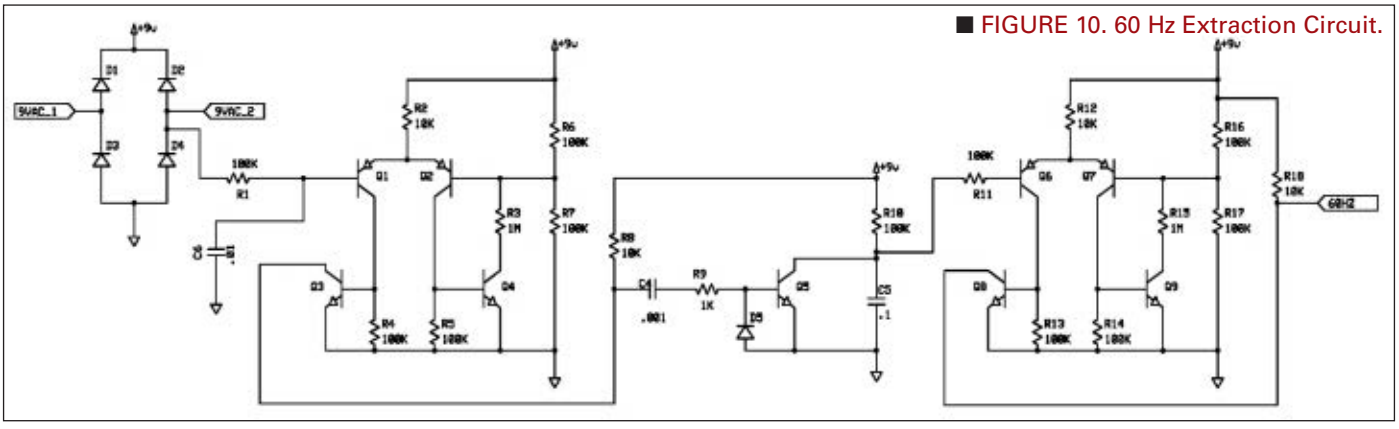
While you could build this clock on perf-board by wiring individual components, with over 2,700 connections you would need to be committed — or at least you should be. Building the clock using the available PCB (printed circuit board) is recommended. The board and/or a full kit are available in the *Nuts & Volts* webstore at **http://store.nutsvolts.com**. An interesting aspect of the PCB is that a parts placement guide is not needed — everything is printed on the PCB. Check out the parts values shown in **Figures 11** and **12**. Building instructions and debugging hints are in the online manual at **www.nutsvolts.com** or my website at **www.kabtronics.com**.

Conclusion

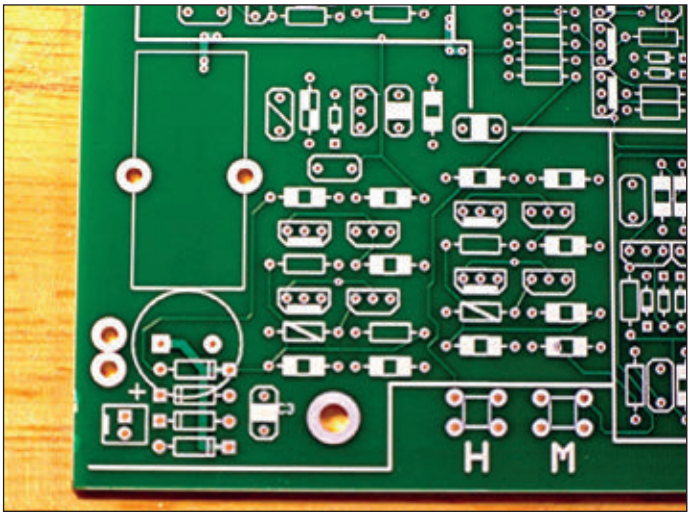
Hopefully, you have learned a thing or two about top-down design, moving from block diagram to transistors and also a bit about counters and flip-flops. If you want to add a course in soldering, consider building the clock. The resulting wall-mountable clock art will be a great memento of your time and efforts. **NV**

continued ...

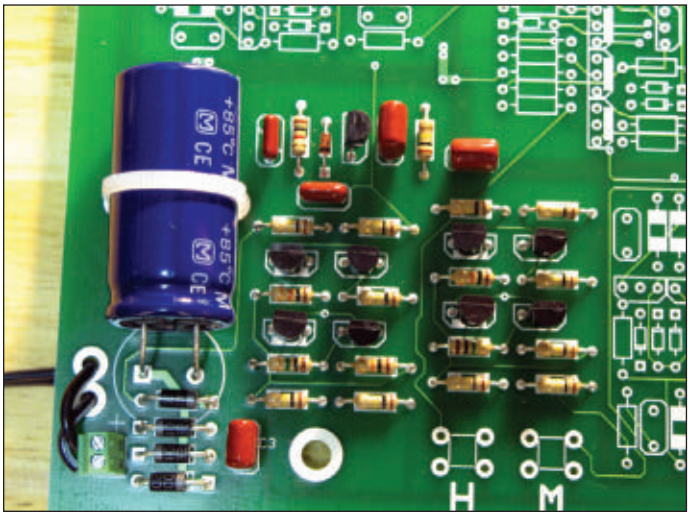
■ FIGURE 10. 60 Hz Extraction Circuit.



■ FIGURE 11. Portion of PCB Showing Silkscreen.



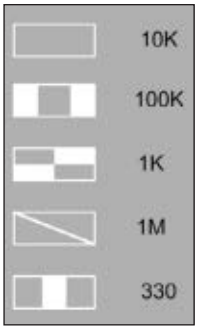
■ FIGURE 12. Loaded Section.



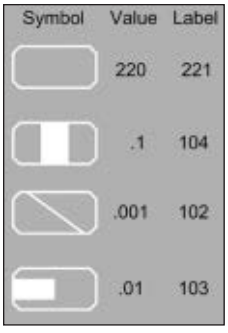
PARTS LIST

❑ 220 pF	75	50 Volt PolyCap
❑ 0.1 µF	15	50 Volt PolyCap
❑ 0.01 µF	1	50 Volt PolyCap
❑ 0.001 µF	2	50 Volt PolyCap
❑ 6800 µF	1	25 Volt Electrolytic
❑ 330	41	1/4 Watt Resistor
❑ 1K	1	1/4 Watt Resistor
❑ 10K	224	1/4 Watt Resistor
❑ 100K	111	1/4 Watt Resistor
❑ 1M	2	1/4 Watt Resistor
❑ 2N3904	165	NPN Transistor
❑ 2N3906	17	PNP Transistor
❑ 1N4148	556	Signal Diode
❑ 1N4002	4	Power Diode
❑ 7-seg	6	Common Anode 0.8 inch LSD8161-11
❑ Single LED	4	3 MM Red LED
❑ TermBlock	1	2 terminal, 0.1 inch spacing
❑ Switch	2	6 mm pc mount
❑ Wall xfmr	1	9 volts AC transformer

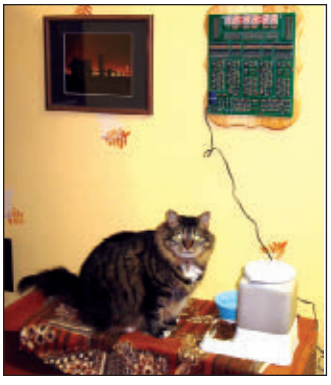
A complete kit or printed circuit board for this project can be purchased from the *Nuts & Volts* Webstore @ www.nutsvolts.com or call our order desk, 800 783-4624



■ Resistor Codes.



■ Capacitor Codes.



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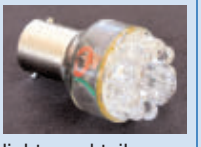

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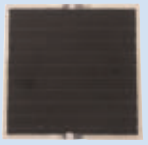

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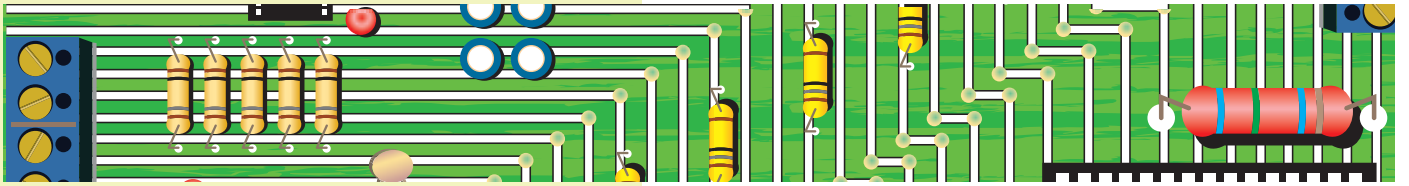

Properly Selecting Electronic Components

Part 1

by Vaughn D. Martin

To realize reliable circuits, one must select the correct components for the job. Without the proper selection, components can drift with temperature and exhibit non-linear and erratic frequency dependent behavior.

This four-part series will address passive components in Parts 1 and 2. Parts 3 and 4 will cover active components. Let's get started with resistors and their variants.

Examples of Improper Component Selection

If this seems more conceptual than practical, use an electrolytic capacitor in a circuit where it receives AC above 20 kHz and you will immediately encounter erratic results. The electrolytic capacitor's foiled pattern, is the culprit (**Figure 1**). It is intrinsically an inductor at frequencies above approximately 1 kHz. A solid tantalum capacitor is a far better choice in this application. This is due to its coiled structure, and an inductor is just that: a coil of wire. A wire wound resistor also acts like an inductor at high enough frequencies for the same reason, i.e., the winding acts as a coil.

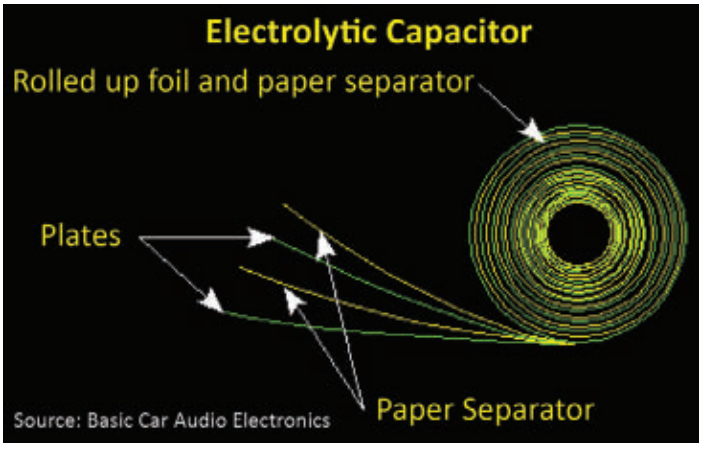

Figure 1. An electrolytic capacitor's interior with its coiled foil construction.

Active Versus Passive Components

A passive component either consumes (but does not produce) energy, is incapable of power gain, or both. An active component is capable of gain (amplification) and possibly directionality. More sophisticated active components can even add intelligence in some manner to the signal or data passing through or being controlled by it.

Resistors

These are the most common passive components. Carbon composition resistors have solid cylindrical resistive elements with embedded metal end caps and attached lead-out wires, (**Figure 2**). Paint or plastic protects them. The resistive element is finely powdered carbon with an insulating material (usually ceramic). A resin bonds this mixture together.

The ratio of the fill material (the powdered ceramic) and the carbon determines its resistance. Higher carbon concentrations have lower resistances. These resistors were predominate until the 1960s. Manufacturing advances allowed other technologies with better specifications such as tolerance, voltage dependence, and stress to substantially gain greater market share.

Carbon Film

Depositing this on an insulating substrate and cutting a spiral in it creates a long, narrow resistive path as shown in **Figure 3**. Varying shapes coupled with the resistivity of carbon provide a variety of resistances. Resistances are available in a range from one ohm to 10 megohms.

Resistivity is the electrical resistance of a conductor of a defined cross-sectional area and known length made of a certain defined material, such as carbon film. The formula is as follows:

R = ρ L / A
ρ = resistivity L = length and
A = cross-sectional area

Thick and Thin Film

Thick film resistors became popular during the 1970s, and most SMD resistors today are of this type. The main difference between thin film and thick film resistors is not the actual thickness of the film, but rather how manufacturers apply the film to the cylinder (axial lead resistors) or the surface (SMD resistors).

Graphics provided by www.electronics-tutorials.ws, EPCOS, and Nonmetallic Inorganic Materials Science City, ETH Zürich, MATL

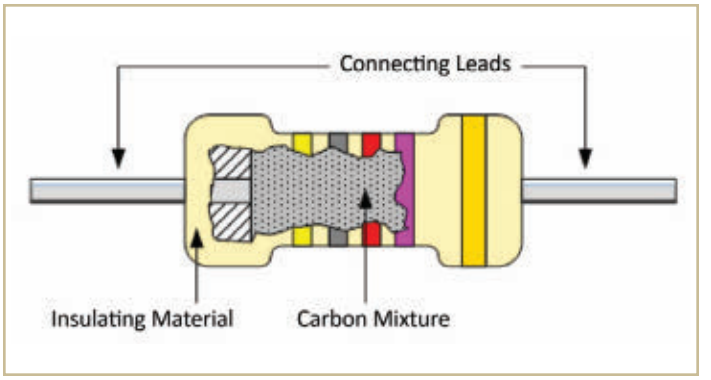

Figure 2. A carbon composition resistor showings its "ingredients."

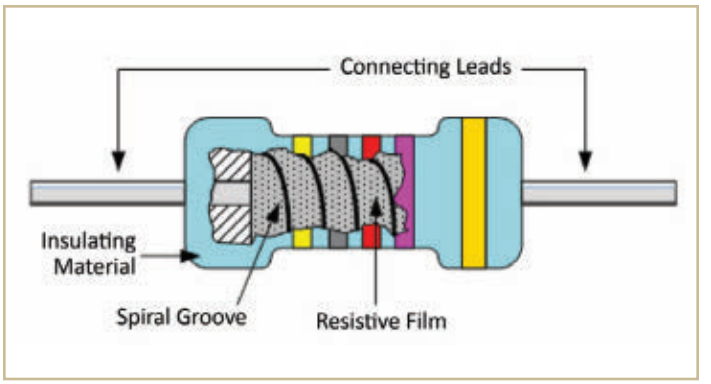

Figure 3. A narrow strip cut in a circular manner around the resistor that determines a carbon film resistor's resistance.

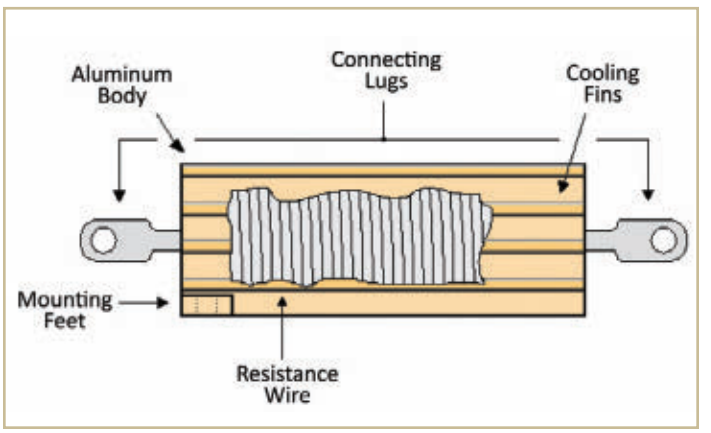

Figure 4. A wire wound resistor partially showing its construction.

The resistance of both thin and thick film resistors after manufacture is not highly accurate; they are usually trimmed to an accurate value by abrasive or laser trimming. Thin film resistors are usually specified with tolerances of 0.1, 0.2, 0.5, or 1%, and with temperature

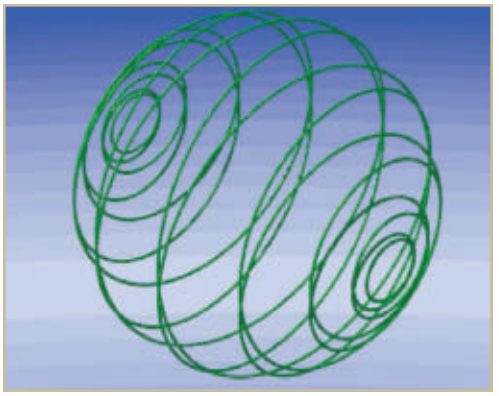

Figure 5. An example of even loops of bifilar coils, conjectured in a manner that when pulsed with AC electrical current, it tends to partially — if not almost totally — nullify the original fields.
(Source: Don E Mitchell Esoterica Images)

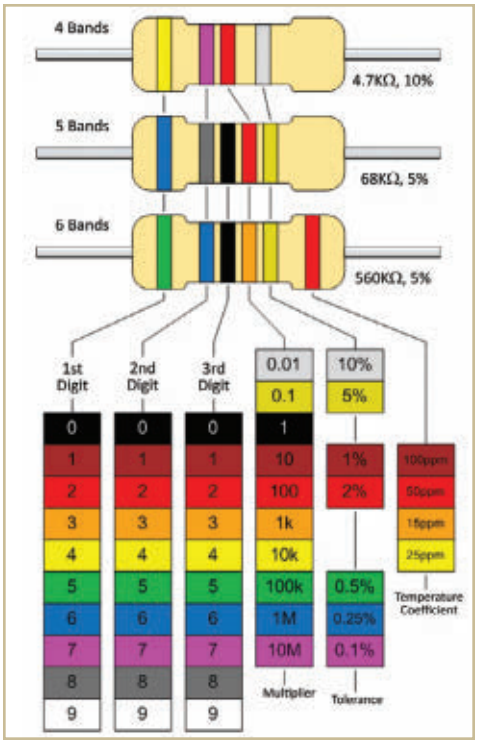

Figure 6. The resistor color code identifying each column used.

coefficients of five to 25 ppm/°C. Thin film resistors are more expensive than thick film resistors. The MELF (Metal Electrode Leadless Face) resistors often use this same technology; however, they are cylindrically shaped resistors that only come in surface-mount [SMD] packages. Also, unlike thin film resistors, their resistance value results from cutting a helix through the coating rather than by etching.

Wirewound Resistors

These have a metal wire wrapped around a ceramic, plastic, or fiberglass core. Two soldered end caps attach the wire to the core. The assembly usually has a baked-on enamel coating protecting it. Check out **Figure 4**. These are usually power dissipation devices and sometimes come with heatsinks. Coiled wirewound resistors innately possess undesirable inductance; however, you can partially minimize this inductance by winding wire in sections in a reversed direction. This practice is called bifilar winding and helps to cancel fields (Figure 5).

> Bifilar winding is a winding of two adjacent insulated wires with currents purposely traveling through them in opposite directions for their field cancelling effect.

Bulk Metal® Foil Resistors

This special alloy foil is several micrometers thick and allows resistor manufacturers to make them with the greatest accuracy and stability. Felix Zandman of Vishay introduced Bulk metal foil resistors in 1962.

Identifying and Using Resistors

Values of resistors most commonly correspond to a color coding scheme (**Figure 6**). The less expensive ones have four bands with the first two band's significant figures followed by a multiplier and possibly a tolerance band. Therefore, a red, red, and red would be 2,200 ohms since the first two reds are two, followed by two, and then it is 10 to the second power or 22 x 100 = 2,200 ohms. No band after that assumes it is a 10% tolerance.

You use resistors in a myriad of ways, realizing that a voltage drop

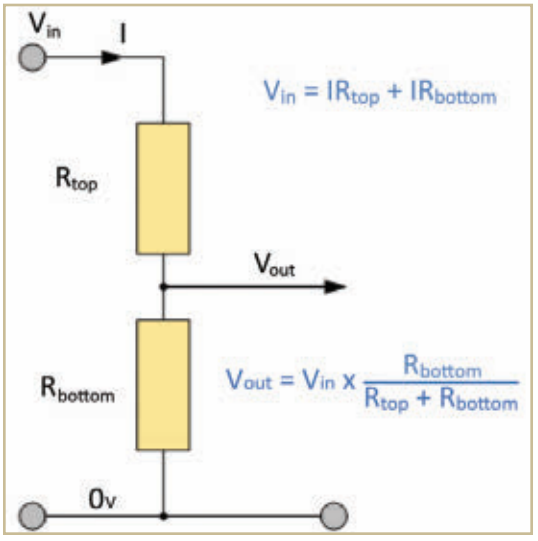

Figure 7. Resistors used in a simple voltage divider configuration.

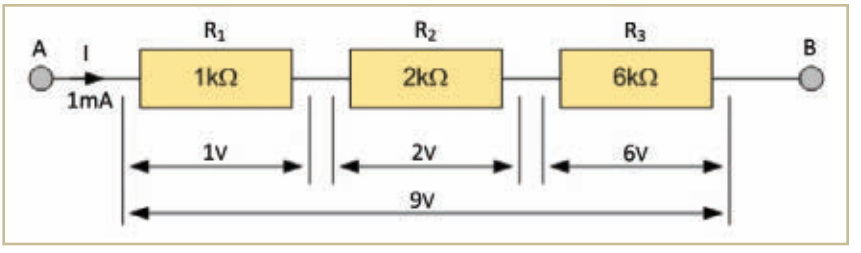

Figure 8. A simplified example illustrating the concept of a voltage drop across a resistor versus its proportional value in a series string of resistors.

occurs as current flows through them. **Figure 7** shows a voltage divider with the proportion of the individual resistor's value versus the total voltage that drops across it. **Figure 8** makes this distinction far more apparent with a nine volt source and nine kilohms of resistance for a one volt drop per kilohm of resistance. You may place resistors in parallel as demonstrated in **Figure 9**. Here, their total resistance is less than that of any individual resistor's value. This arrangement allows greater current flow since it splits the overall current through three distinct paths; one path per resistor.

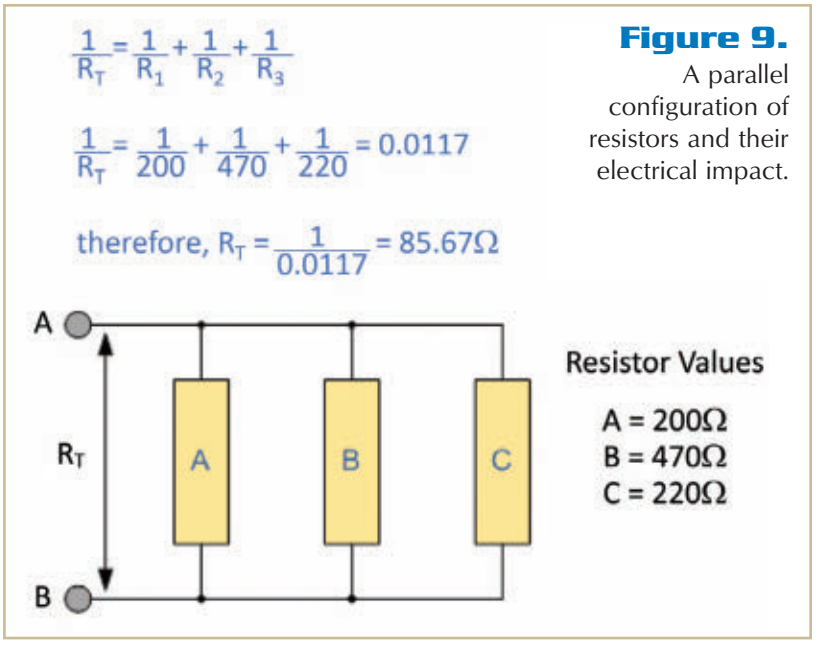

Figure 9. A parallel configuration of resistors and their electrical impact.

Specialty Resistors

You can think of **Figure 10** as a varistor (to be discussed) on steroids. These protect critical devices — e.g., a receiving or transmitting antenna — by sidetracking or absorbing electrical energy from lightning strikes. They do so by routing the current directly to ground.

Secondly, light dependent resistors (LDRs) inversely change resistances with the intensity of the light falling upon them (**Figure 11**). These are also called photocells. In strong light, their resistance can be as low as a few ohms. In the absence of light, it can be in the tens of megohms. Its base material is predominately either cadmium sulfide or lead sulfide.

Interestingly, LDRs are sensitive to different colors of light. Therefore, their datasheets often express resistances at UV, IR, and different visible colors. I have seen homemade photo hobbyist color temperature meters based on LDRs. To see an LDR used to determine your Stratum Corneum Hydration and Skin Erythema, go to **http://dermatology.cdlib.org/DOJvol7num2/original/instrumentation/atkins.html**. The degree of skin blood flow and stratum corneum (SC) hydration in response to clothing are associated in a practical aspect. This is the perception of fabric comfort the textile industry uses.

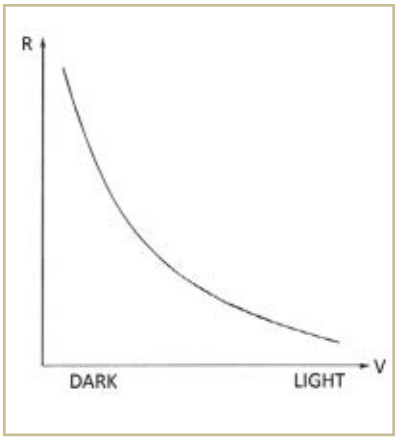

Figure 11. A light dependent resistor's transfer function or how it responds to various levels of incident light intensity.

Figure 10. A lightning arrestor with an internal resistive insert that is — in effect — a varistor on steroids.

The drawback to LDRs is they are fairly slow to varying light levels (typical two to three second response times). If you require a faster optoelectronic device, consider using either a photodiode or a phototransistor.

Before delving into on varistors, I suggest reading the November '08 *N&V* "Developing Perspectives" by Bryan Bergeron. This gives an interesting example of how he used varistors in a practical and useful way.

Varistors

Variable resistors are two-electrode zinc oxide semiconductor devices with a distinctively voltage-dependent nonlinear resistance and a symmetrical V/I characteristic curve (**Figure 12**). This resistance drops with increased applied voltage and vice-versa, making them ideal to protect sensitive equipment from power or lightning strikes. They shunt this energy to ground and are great surge arresters in power transmission

Reference

1) ***www.geofex.com/article_folders/potsecrets/potscret.htm***
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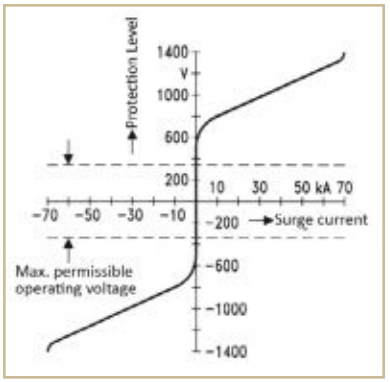


Figure 12. The protection level, surge current, and maximum operating voltage of a varistor.

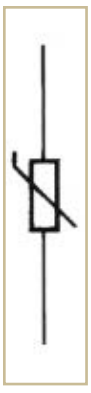


Figure 13. A varistor's schematic symbol.

Figure 14. An actual disc varistor typically used in surge arrestors and inline AC line protectors.

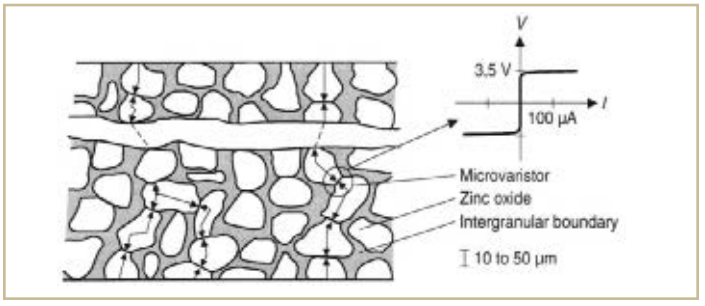


Figure 15. The internal atomic structure of a varistor showing a conduction path and its oxides.

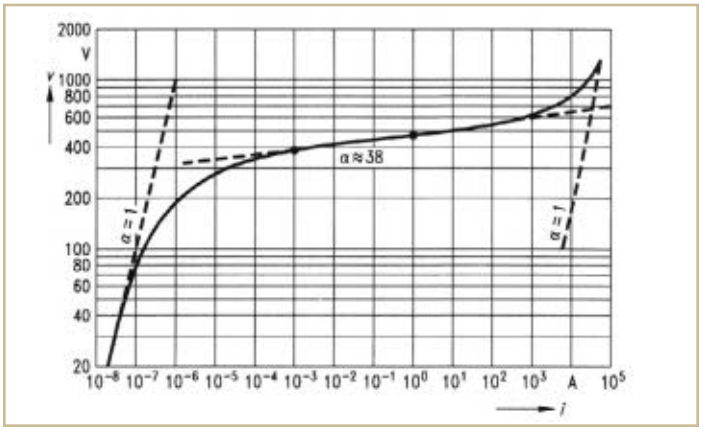


Figure 16. A real actual V/I characteristic of a metal oxide varistor.

schemes. **Figure 13** shows the schematic symbol and **Figure 14** shows an actual varistor.

Varistor Grains

During manufacturing as they cool and while still in the liquid phase, a rigid amorphous coating around each zinc oxide grain forms. This yields a microstructure of zinc oxide grains that are isolated from each other by a thin continuous intergranular phase. It is this complex, two-phase microstructure that yields this desired purposely desired nonlinear characteristic.

Figure 15 is a simplified illustration of its conduction. The zinc oxide grains are highly conductive, and the intergranular boundary formed with other oxides is highly resistive. The points where zinc oxide grains meet causes sintering or "microvaristors" — comparable to symmetrical zener diodes at approximately 3.5V. The electrical behavior in Figure 15 results from the number of microvaristors connected in series or parallel.

Sintering is the welding together and subsequent growth of contact areas between two or more initially distinct particles. This occurs at from one-half up to the full melting point of the materials. Sintering occurs more rapidly with smaller particles. This is why the process is so popular in powder metallurgy and in firing of ceramic oxides.

The V/I curve is a straight line between 10^{-4} and 10^{3} amps (see **Figure 16**). **Figure 17** shows the change in static resistance R = V/I for a typical varistor. The resistance is > 1 megohm in the range of the permissible operating voltage, but can drop by 10 orders of magnitude in cases of overvoltage.

Standard IEC 60060 defines the maximum non-repetitive surge current by an 8/20 µs waveform (rise time 8 µs/decay time to half value of 20 µs). Check out **Figure 18**. This waveform approximates a rectangular wave of 20 µs. The derating curves of the surge current — defined for rectangular waveforms — show a knee between the horizontal branch and slope at 20 µs.

The same international standard requires relatively long durations for testing surge currents and maximum energy absorption capability. A rectangular wave of 2 ms is commonly used for this test (**Figure 19**).

The most common type of varistor is the Metal Oxide Varistor (MOV). This contains a ceramic mass of zinc oxide grains in a matrix of other metal oxides (such as small amounts of bismuth, cobalt, manganese) sandwiched between two metal plates (the electrodes). The boundary between each grain and its neighbor forms a diode junction which allows current to flow in only one direction.

Interestingly, Metal Oxide Semiconductor (MOS) CO (carbon monoxide) detectors use heated tin oxide. When CO is present, the heated tin oxide reacts with it and sounds an alarm. There are three basic types of CO sensors:

- The most sensitive and (unfortunately) most expensive is the electrolytic sensor.
- A colorimetric sensor measures the build-up of CO over time but takes 48 hours to re-set once activated.
- The least expensive and most common CO sensor is the MOS detector. This can also detect other gases including chlorine bleach and certain silicones. This additional detection capability explains some cases of false alarms.

The follow-through current from a lightning strike may generate excessive current that permanently damages a varistor. The primary varistor breakdown is localized heating caused by thermal runaway. This is due to a lack of conformity in individual grain-boundary junctions, which leads to the failure of dominant current paths under thermal stress. Varistors can absorb part of a surge; however, they do not absorb a significant percentage of a lightning strike.

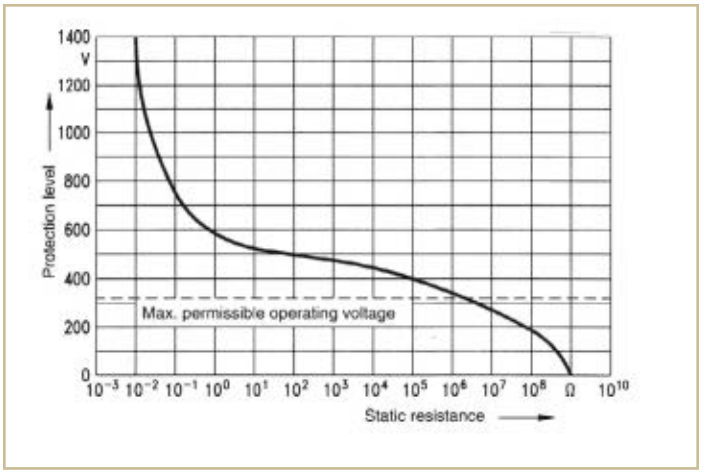


Figure 17. The static resistance of a metal oxide varistor versus its protection level.

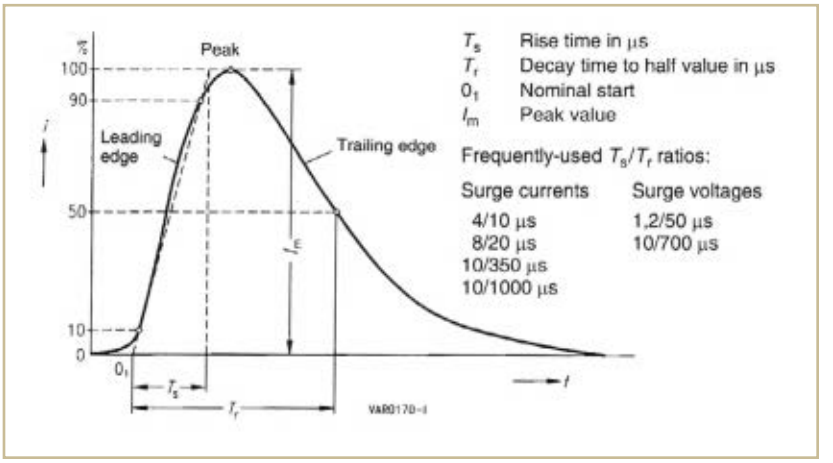


Figure 18. The maximum non-repetitive surge current is defined by an 8/20 µs waveform (rise time 8 µs/decay time to half value 20 µs) according to IEC 60060.

A joule is a unit of electrical energy equal to the work done when a current of one ampere passes through a resistance of one ohm for a one second duration.

Varistor Useful Life

Life expectancy of a varistor is virtually synonymous with its energy rating. As MOV joules increase, the number of transient pulses increase and the "clamping voltage" during each transient decreases.

Variable Resistors

Now that you know all about the various technologies and a few applications associated with resistors, what if you need a different resistance once the resistor is already within your planned or prototype circuits? This inability to adjust resistance can be exasperating. This is why there are variable resistors called potentiometers (pots, for short). Pots tend to be larger and often panel mounted, (**Figure 20**).

Most modern circuits are smaller, draw less current, and generally use variable resistors commonly called

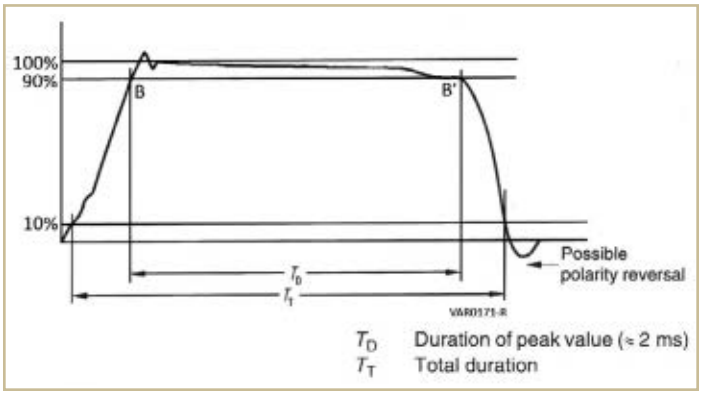


Figure 19. Surge currents of relatively long duration are required for testing maximum energy absorption capability. A rectangular wave of 2 ms is shown here as required by IEC 60060.

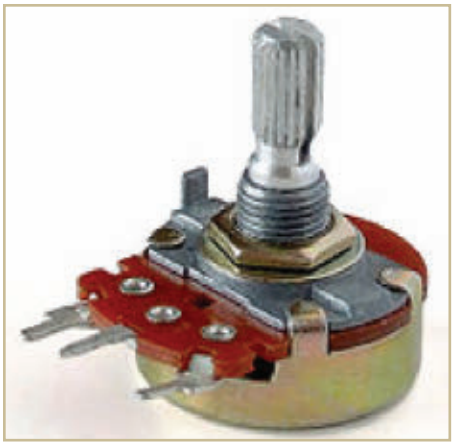


Figure 20. A larger wire wound pot that is panel mountable and quite sturdy, appearing on the front panel of industrial instrumentation.

Figure 21. A variety of small trimmer variable resistors.

components, and are physically smaller and capable of dissipating less power than the larger wire wound pot Figure 20 demonstrated.

Some trimmers are quite precise and offer very good resolution. **Figure 22** shows a cut-away view of a multi-turn trimmer. Note the wiper (piece of metal serving as a contact) that slides along the wire wound column. It advances as you turn it by its end slot with a screwdriver. This varies its resistance. Since the wiper is metal, it offers very little resistance, and current seeks the path of least resistance. Therefore, the current does not go through the entire winding of wire, but diverts through the wiper. Varying its position along this wire column also varies its effective resistance. There are also cermet trimmers if the inductance inherent in a wire wound trimmer is potentially detrimental to your application.

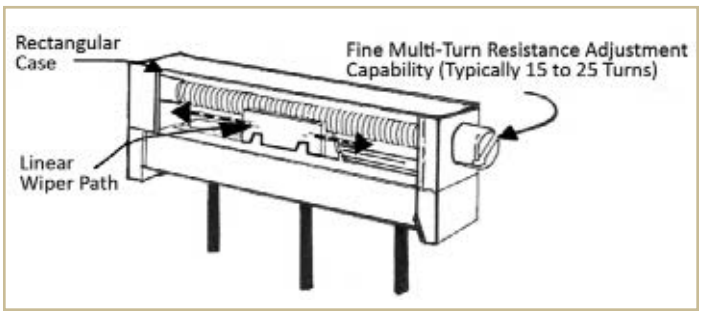


Figure 22. A rectangular multiple-turn trimmer showing a cut-away view.

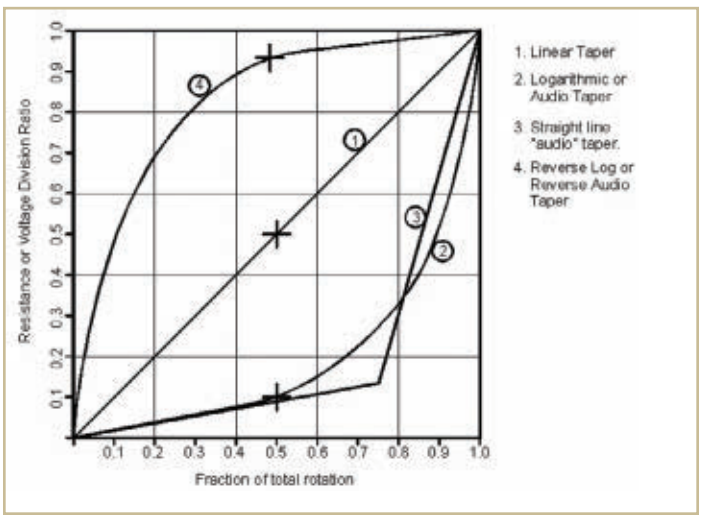


Figure 23. A plot of a logarithmic versus a linear pot response to rotation versus its resistance.

cermet trimmers (**Figure 21**). These cermet trimmer pots are mostly printed circuit board mountable or SMD

Cermet is a durable substance able to withstand high temperatures, formed by bonding ceramic particles with metal. A cermet is therefore comprised of ceramic (*cer*) and metallic (*met*) materials. A cermet has the optimal properties of both a ceramic — such as high temperature resistance and hardness — and a metal, with the ability to undergo plastic deformation.

Linear versus Logarithm or "Audio" Taper Pots

If you rotate a 10 turn pot's shaft five turns, you would expect one-half of the maximum resistance. This is true if the pot has a linear taper. However, there are special pots and trimmers (but mostly pots) that have their resistance progressing at a logarithmic rate. That is why we sometimes call them audio taper pots. Notice that a linear pot's resistance progresses in a straight line — thus linear (**Figure 23**).

Psychoacoustics is the science of human perception of sounds. Fundamental to this is measuring the "intensity" range of audible sounds. This is enormous. Therefore, you measure sound pressure level logarithmically. This is precisely why linear taper pots are so useful in sound applications. As you may recall, logarithms are useful for expressing numbers over a very large range, such as dB (decibels).

A logarithmic pot shows a distinctly parabolic func-

Figure 25. Sliding logarithmic taper pots used side-by-side in corresponding frequency ranges to make the sound output match the pot slider settings with respect to their amplitude adjustments. There are two sets of these; one for each stereo channel.

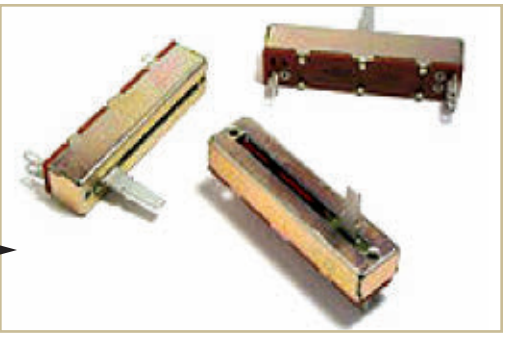


Figure 24. Slide functional logarithmic pots used in audio applications, such as graphic equalizers.

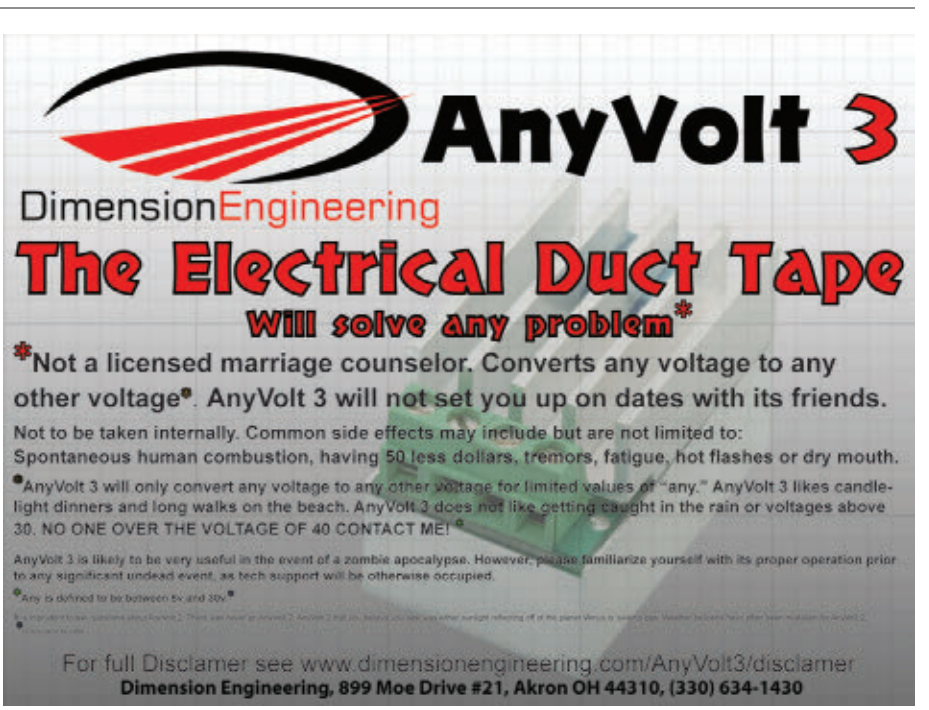
Figure 27. Another version of a turns-counting dial that has a multiple revolution pot fused into the turns counting assembly and requires no attachment to the pot's shaft as is the case in Figure 26.

tion. This is with respect to its resistance versus the amount of rotation that you turn it. If this intrigues you, Reference 1 examines this in detail. Audio graphic equalizers use these types of pots but only in slide forms (**Figure 24**).

Figure 26. A turns-counting dial that attaches to a multiple revolution pot.

A graphic equalizer is an electronic component with adjustable sliding controls that correspond to a frequency plot. The sliding controls in the middle correspond to the mid-range frequencies; on the low end, those sliders control lower frequencies, etc., yielding a realistic plot of the audio spectrum. Raising the sliding controls increases that frequency's amplitude (**Figure 25**).

Some linear pots are quite precise in their rotation versus resistance value. These are usually 10 turn pots that capitalize on this feature. A few manufacturers make turns-counting dials for these types of precision pots; look at **Figures 26** and **27**. These exploit this phenomenon. With precise A/D converters and electronic displays being so inexpensive now, they are becoming less popular. **NV**



Introduction to Heatsink Selection & Installation

by John E. Post

"Ouch!" I exclaimed as I examined the almost perfect circle surrounding a stylized "M" (for Motorola) that was branded into the end of my index finger after touching the case of a power transistor to see if it was "warm." This was my introduction to "heatsink selection for power semiconductors" I received as a young experimenter building a power supply — a lesson I have not forgotten several decades after the event. The purpose of this tutorial is to provide an introduction to basic concepts of heatsink selection and installation for power semiconductors, and possibly save you a few burned fingers and burned out devices, as well.

Power semiconductors (both transistors and integrated circuits) may potentially dissipate large amounts of electrical power in the form of thermal energy or heat when the devices handle large currents. In order to find the heat load in watts the device must dissipate, simply multiply the voltage dropped across the device by the current through it. For example, the device will dissipate 20W if the device current is 4A with a voltage drop of 5V. Internally, the heat is generated across the semiconductor junction (i.e., that location where the n-type and p-type semiconductor materials join inside the device). If the heat is not removed, the temperature across the semiconductor junction — referred to as the junction temperature (T_j) — will rise until it exceeds the maximum junction temperature (T_{jmax}) which usually leads to destruction of the device.

Just as important, it is necessary to keep T_j as low as possible to ensure the reliability, service life, and performance of the semiconductor device. Typical values for the maximum junction temperature specified by semiconductor manufacturers range between 125°C to 150°C, although some devices— the 2N3035 NPN transistor for example — are rated for operation up to 200°C. A rough rule of thumb is that the operating life of semiconductor devices decreases by half for every 10°C rise in temperature above 100°C — equivalent to an exponential decrease in operating life with increasing temperature. [1]

A heatsink is a mass of metal that conducts heat generated by power semiconductor devices to a location with a cooler temperature — usually the ambient air — where it is removed by natural convection. A properly designed heatsink will maintain the junction temperature of the semiconductor devices well below the maximum operating temperature while minimizing the impact on the budget of the project. **Figure 1** shows several small heatsinks designed for TO-39 and TO-220 case styles which are suitable for dissipating a few watts of power and are compact enough that they could be mounted on the circuit board itself. Higher power dissipations in the tens of watts are achieved by mounting a large heatsink on the back of the chassis which

FIGURE 1. Heatsinks for TO-39 and TO-220 case styles.

FIGURE 2. A power semiconductor with a TO-3 case style mounted to a heatsink attached to the back of a chassis.

maximizes heat dissipation due to natural convection (see **Figure 2**). Increased heat dissipation beyond that given by natural convection — available, of course, at increased cost — may be obtained by either forced convection provided by a mechanical fan or by circulating some type of liquid coolant through the heatsink to remove excess heat. The sidebar discusses the concept of a thermal circuit in order to define some common terms and introduces the mathematical description of the problem of transferring heat from the semiconductor junction to the environment.

To provide an example, we'll apply this information to the problem of selecting a heatsink appropriate to provide adequate heat dissipation for a LM309 five-volt regulator used in a typical power supply application.

Heatsink Design Theory

It is common to apply an electric circuit analogy in order to introduce the basic steady-state thermal resistance model that relates the quantities of heat dissipation, temperature rise, and thermal resistance. **Table 1** shows that the electrical quantities of charge, current, potential, and ohmic resistance are analogous with the thermal quantities of heat, power, temperature, and thermal resistance, respectively. Because of this analogy, Ohm's Law — which describes the relationship between voltage, current and resistance in an electric circuit — also describes the corresponding relationship between power dissipation, temperature, and thermal resistance in a thermal system or "circuit."

ELECTRICAL SYSTEMS		THERMAL SYSTEMS	
Quantity	Unit	Quantity	Unit
Charge: Q_c	Coulombs	Heat: Q_D	Joules
Current: I	Amperes	Power Dissipation: P_D	Watts
Potential: V	Volts	Temperature: T	°C
Resistance: R	Ohms	Resistance: θ	°C/W

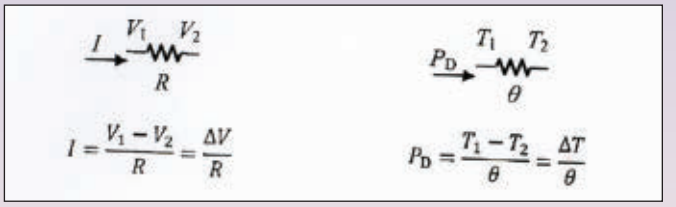
TABLE 1. Analogy between electrical quantities and thermal quantities.

Figure 3 illustrates this idea and shows that just as the electric current I in a resistor results from the potential difference ΔV across a resistance R in an electrical circuit, thermal power flow P_D produces a temperature difference ΔT across the thermal resistance in a thermal circuit. Solving the thermal equation given in the figure gives $T_1 = P_D \bullet \theta + T_2$. For the problem of heatsink design, T_1 is the desired operating junction temperature T_j; T_2 is the temperature of the ambient air T_A; P_D is the power dissipated by the semiconductor device, and θ is the total thermal resistance between the semiconductor junction and the environment; by substitution this results in the thermal equation $T_j = P_D \bullet \theta + T_A$.

The thermal equation shows that two terms contribute to the junction temperature T_j. The first contribution is due to the power dissipation of the semiconductor device multiplied by the thermal resistance between the semiconductor junction and the ambient air. The second contribution is due to the temperature of the ambient air. In order to maintain the junction temperature T_j at a constant value, as the power dissipation P_D increases, the heatsink designer must either apply air conditioning to lower the environmental temperature T_A, or reduce the thermal resistance between the semiconductor junction and the ambient air. Normally, the most cost-effective approach is to install a heatsink with a small enough thermal resistance in order to maintain the junction temperature below some desired value, such as 100°C.

Is it possible to verify that the heatsink installation is working? The right side of **Figure 4** suggests a method for applying the thermal equation in order to verify that the heatsink is adequately sized. If the power dissipation P_D and case temperature T_C are known (perhaps by clamping a temperature probe to the case after applying a bit of thermal grease), the thermal equation becomes $T_J = P_D \bullet \theta_{JC} + T_C$. This relationship shows that the temperature at the semiconductor junction may be found by adding the case temperature T_C to the product of the power dissipation P_D and the junction-to-case thermal resistance θ_{JC}.

FIGURE 3. The application of Ohm's Law to electrical (left side) and thermal (right side) systems.



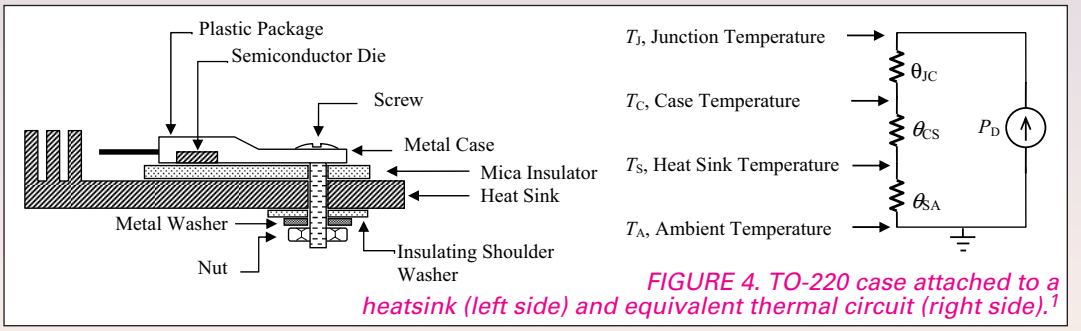


FIGURE 4. TO-220 case attached to a heatsink (left side) and equivalent thermal circuit (right side).[1]

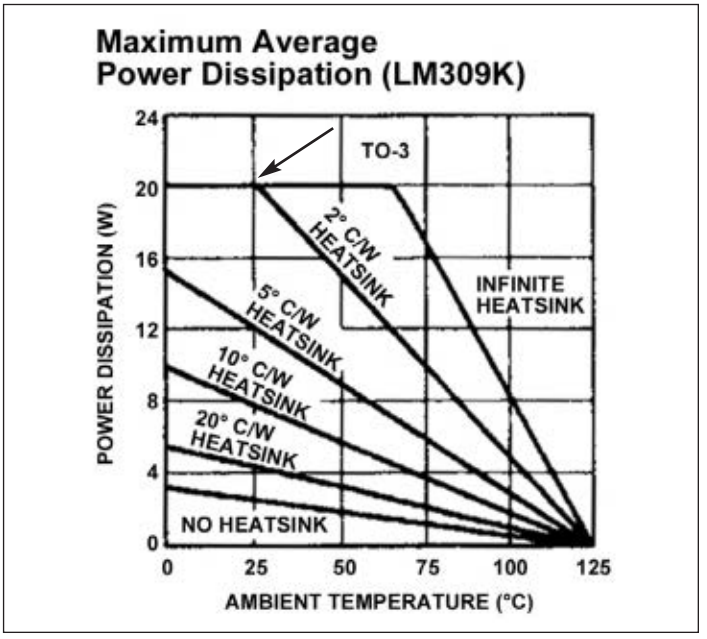
Heatsink Installation

A typical heatsink installation is shown on the left side of Figure 4 which shows the cross-section of a power semiconductor; in this case, one with a TO-220 package. When the device is in operation, the temperature of the semiconductor junction rises causing heat to flow from the semiconductor die through the metal case and mica insulator out to the metal heatsink where it is dissipated into the atmosphere. The metal heatsink is usually bolted onto the metal chassis so it is necessary to electrically — but not thermally — insulate the power semiconductor from the heatsink by separating the two with an electrical insulator such as a mica washer or silicon pad.

Typically, both sides of the insulator are covered with silicon thermal grease. The purpose of the grease is to fill any microscopic air pockets that would otherwise exist between the materials because air is a very good insulator. This produces air-free joints which minimize the thermal resistance through which heat must flow and reduces the temperature rise where different materials are joined. It is important to use just enough grease to fill the voids, but no more than that or the additional grease itself will serve as a thermal insulator, increasing the thermal resistance.

The right side of Figure 4 shows the equivalent thermal circuit. In this circuit, the total thermal resistance θ between the temperature of the semiconductor die and the ambient air temperature — given as °C/W — is the sum of the thermal resistance between the junction and the package case, θ_{JC}, the thermal resistance between the package case and the heatsink, θ_{CS}, and the thermal resistance between the heatsink and the surrounding air

FIGURE 5. Maximum average power dissipation (LM309K)[2]. The arrow indicates the point on the figure that demonstrates that a 2.0°C/W resistance heatsink is able to dissipate 20W of power at an ambient temperature of 25°C which agrees with the sample calculation discussed here.



θ_{SA} or $\theta = \theta_{JC} + \theta_{CS} + \theta_{SA}$. Values for each of these thermal resistances are usually found in the manufacturer's datasheet for the semiconductor device and listed in the manufacturer's information for each heatsink. Approximate values for the junction-to-case resistance, θ_{JC}, are 0.5–2.5°C/W, for the package-to-case resistance, θ_{CS}, 0.5–1.5°C/W, and approximately 4°C/W and up for heatsink to ambient air, θ_{SA}, depending upon the heatsink's shape, material, mass, and construction.

Heatsink Design Example

Let's illustrate these concepts by designing a heatsink that will allow us to extract the maximum performance from a LM309 five-volt voltage regulator IC which has a maximum power dissipation of 20W[2]. The LM309 was chosen because the manufacturer conveniently provides data that relates the device's power dissipation, required heatsink thermal resistance, and ambient operating temperature which will allow us to verify our calculations.

First, it is interesting to note that the test conditions for the electrical characteristics specified for the device were taken at a junction temperature, Tj, of 25°C, which implies the device is either mounted on an infinite heatsink or the environmental temperature during the test was reduced by air conditioning. The datasheet also states that the maximum operating junction temperature for this device is only 125°C, so we will design the heatsink so that the device temperature does not exceed this value, although a more conservative design would use a lower value such as 100°C.

Substituting these values into the rearranged thermal equation in Figure 3 gives

$$\theta = \frac{\Delta T}{P_D} = \frac{125 - 25}{20} = 5.0$$

the maximum value of thermal resistance between the semiconductor junction and the ambient air that our design can tolerate without overheating. According to Note 3 in the datasheet, the thermal resistance between the junction and the package case, θ_{JC}, is 2.5°C/W. Additionally, typical values for the thermal resistance between the package case and the heatsink, θ_{CS}, are around 0.4-0.6°C/W when using a mica washer coated with silicon grease, so we'll use a mid-range value of 0.5°C/W. Thus, the thermal resistance between the heatsink and the surrounding air, θ_{SA}, must be less than 5.0 – 2.5 – 0.5 = 2.0°C/W. This result agrees exactly with the manufacturer's figure for maximum average power dissipation for the LM309K reproduced in Figure 5, which shows that a 2.0°C/W resistance heatsink is able to dissipate 20W of power at an ambient temperature of 25°C.

A review of heatsinks produced by one manufacturer (Wakefield Engineering) indicates that a heatsink thermal resistance of 2.0°C/W is just outside of what is possible without forced cooling. For example, the Wakefield 641A

heavy-duty heatsink has a thermal resistance with natural cooling of 2.4°C/W, versus a thermal resistance with forced cooling of 0.9°C/W @ 250 LFM air flow. Thus, the designer must either limit the maximum power dissipation of the voltage regulator to 18.5W (100°C/5.4°C/W) or provide for forced cooling of the heatsink with mechanical ventilation in order to keep from exceeding the device ratings.

Finally — by way of comparison — Note 3 in the LM309K datasheet also states that the thermal resistance of the TO-3 case to ambient air, θ_{CA}, is approximately 35°C/W. Thus, without a heatsink power dissipation is limited to less than 2.9W, also in good agreement with the result shown in **Figure 5**.

Conclusion

It is important to maintain the junction temperature of semiconductor devices below their operating limits in order to ensure the device's reliability, service life, and performance. Usually, the most cost-effective approach to accomplish this is to physically connect the device to a heatsink by way of a conducting path with low thermal resistance.

This article demonstrated how to determine the minimum total thermal resistance by dividing the difference in temperature between the semiconductor junction and the ambient environment by the required power dissipation. Then, it is possible — after subtracting off the junction-to-case and case-to-heatsink thermal resistances from the total thermal resistance to select a heatsink with small enough thermal resistance to provide power dissipation that is adequate for the proposed application. **NV**

Footnotes

1. Motorola Semiconductor Technical Data Sheet AN1083, Basic Thermal Management of Power Semiconductors, 1990.

2. National Semiconductor LM109/LM309 5-Volt Regulator Data Sheet.

Are there certain topics you'd like to see presented in our How-To series? Then tell us! Email **editor@nutsvolts.com** with your requests.

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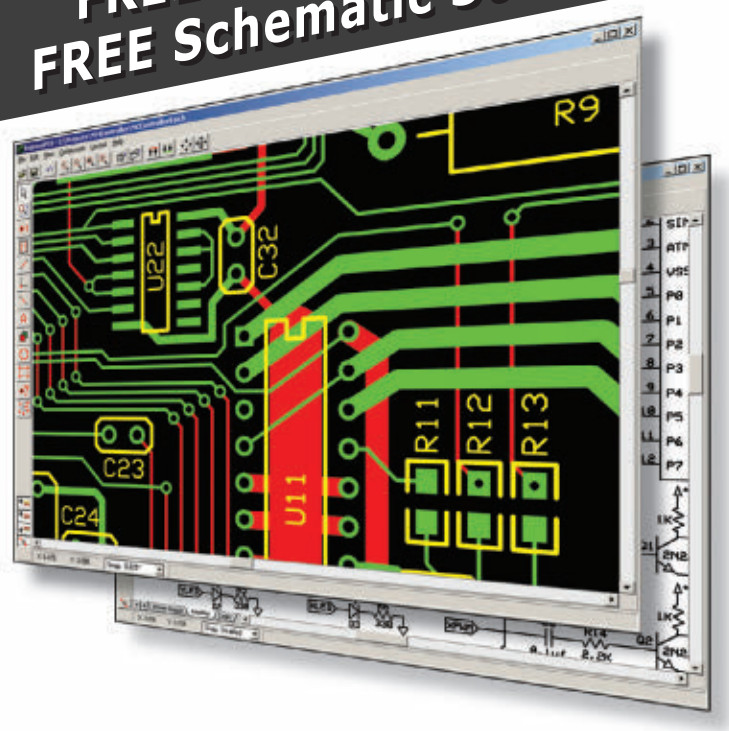

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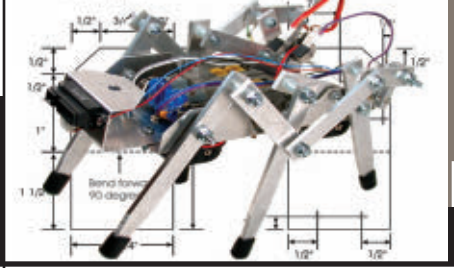
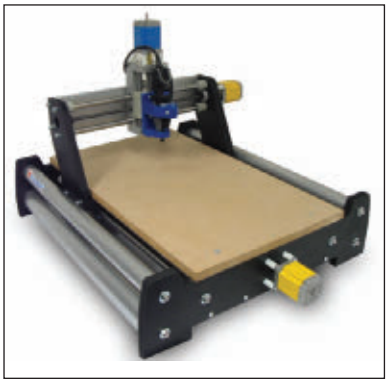


■ BY VERN GRANER

THE PROBOTIX FIREBALL V90 CNC VISITED



HAVEN'T WE BEEN HERE BEFORE? If the machine shown here looks familiar, it's because we first introduced you to it back in the December '08 column. In that article, we detailed the PROBOTIX Fireball v90 — one of the first high-accuracy/sub-$1,000 CNC systems on the market. We explored what came in the package, detailed how the machine went together, and gave a few examples of how the machine could be used. We then shared our experiences as newbies using the machine in a high-pressure environment for a couple of non-stop days at Maker Faire Austin. At that event, the machine was used to cut recycled CD-ROMs into gears, key chains, and even a set of snazzy earrings (Figures 1 - 3)!

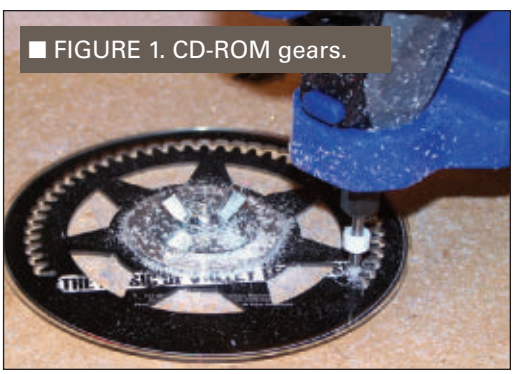
Since then, we've had time to become more familiar with the v90 and — though there's nothing wrong with cutting CD-ROMs into earrings — we figured it would certainly be more practical to use the machine to create something useful for the electronics hobbyist. This month, we're going to describe how our v90 has evolved since its debut and then show how the machine can be put to some real work making practical items for use in your every day electronic and robotic projects.

READY TO RUN? YES!

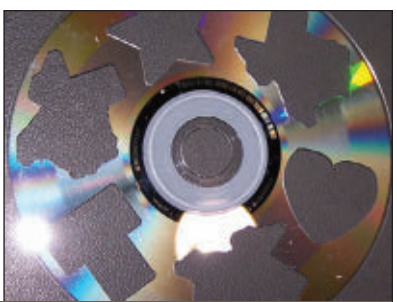
When we originally received the V90 back in August '08, the hardware came with all the required electronics components, but you were expected to provide (or create) your own electronics enclosure. In addition, you had to solder/heat shrink the wires to each of the stepper motors and then attach the ends of the wires to each of the motor controller boards using screw terminals. Though this approach worked fine for us and is still a viable option for folks who expect their CNC system to "stay put," having the wires screwed to terminals in our system didn't lend itself to portability.

Any time we needed to move the machine, we had to unscrew each wire from the stepper controllers, pull them out of the hole in the enclosure, and then set the control electronics inside the enclosure for transport (**Figure 4**). When reassembling, we had to reverse the process and make sure we got all the stepper motors wired back to their controllers correctly. Also, using our method of electronics assembly (i.e., screwing everything down to a hunk of wood), you have to take special care to avoid both the spinning fan blades and possible short circuits with the exposed electrical connections (**Figure 5**).

To avoid all this hassle, a new "Ready To Run" option allows you to purchase all the electronics factory assembled in a nice, fan cooled custom cabinet (**Figure 6**) with

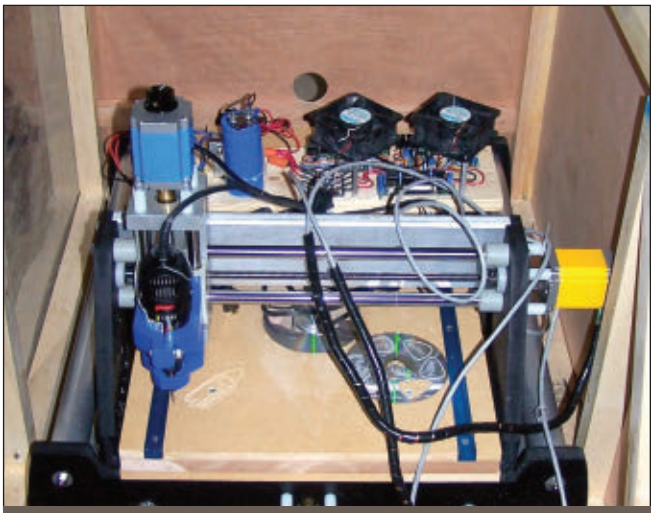


■ FIGURE 1. CD-ROM gears.

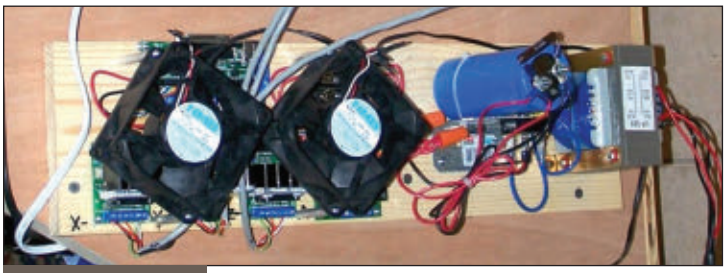


■ FIGURE 2. CD-ROM cut into shapes for key chains.

■ FIGURE 3. At Maker Faire, a young passerby turned a pair of Texas key chains into earrings.



■ FIGURE 4. The v90 ready for transport after disconnecting the stepper motors.



■ FIGURE 5. The v90 power supply, motor controllers, and cooling fans.

■ FIGURE 6. The Ready To Run case contains the power supply and the motor controllers.

clearly labeled DIN style connectors on the back (**Figure 7**) and the power supply and associated board enclosed professionally inside (**Figure 8**). This certainly makes set-up a snap and avoids both exposed electronics and stepper mis-wiring issues as the motors with the Ready To Run kit come with the DIN plugs pre-attached (**Figure 9**).

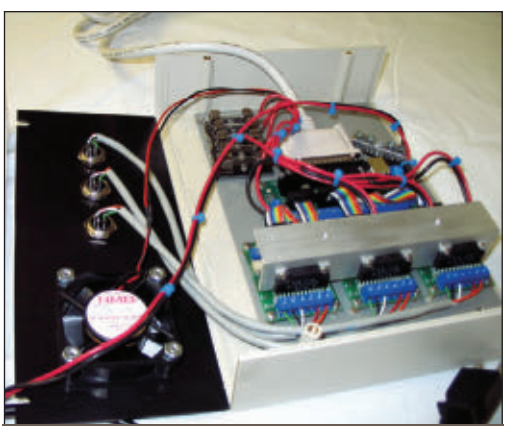
JUST LIKE ONE OF THE FAMILY

One of the nice things about a product like the v90 is the community that grows up around it. There is a very active and helpful group of folks on the PROBOTIX mailing list, in fact, even Len Shelton (the owner of PROBOTIX) is known to make frequent appearances to answer questions. Through reading the list and having discussions with other owners, we graduated from a Dremel rotary tool, to a Porter Cable router, and finally worked our way up to a Bosch Colt. Upgrading tools was a simple process as PROBOTIX makes various tool mount adapters to help facilitate experimenting with different cutting tools, including one for the Colt (**Figure 10**) which we currently have on our system.

Without getting too involved in the process of moving up through the various cutting tools, the bottom line was the Bosch Colt displayed the least amount of runout. "Runout" is basically the amount that the cutting bit deviates from a perfectly circular, perpendicular rotation. Excessive runout in your cutting system can lead to broken bits, inaccurate cuts, and other undesirable results. (For more details on runout, see the **Resources** section.) The last piece of the puzzle (in regard to the mechanical aspect of the system) is that when you are asking the machine to perform a job, it's crucial to have the right bit for that job! There are literally hundreds of different styles and sizes of bits, and it helps to have expert advice to both purchase the right part and to ensure a long life for that part. After buying (and breaking) quite a few bits from discount sources, Len suggested we speak with the folks at **PreciseBits.com**. After reading their website, we ordered bits for the two things we really wanted to do: making circuit boards and cutting case bezels. So, with our v90 converted to the new Ready To Run kit, the Bosch Colt router firmly in the grasp of the z axis, and fitted with some shiny new bits from **precisebits.com**, it seemed it was time to spin up the router and cut some stuff ... or was it?

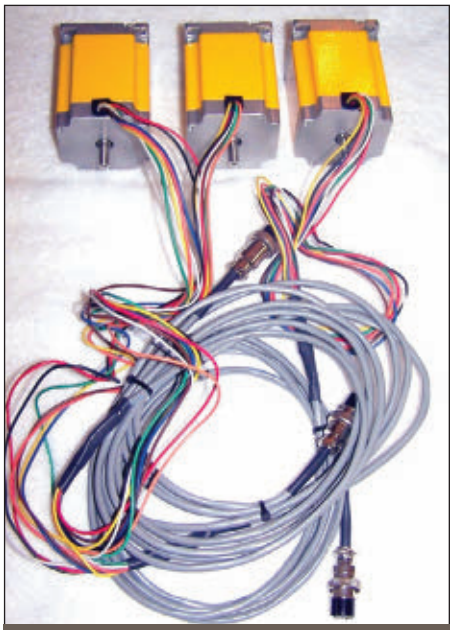
THE EAGLE HAS LANDED

Before we fire up the router and start making dust, we have to begin by opening up the computer and dealing with some software first. There are many paths to get from



■ FIGURE 8. Inside the Ready To Run case.

■ FIGURE 7. Rear view of the Ready To Run case.



■ FIGURE 9. Stepper motors with wires attached and terminated with DIN plugs.

■ FIGURE 10. The Bosch Colt router in the PROBOTIX Fireball v90.

your design to a finished piece (see resources for software choices), but we typically use EAGLE if we intend to use the resulting layout to cut a printed circuit board (PCB) using the v90. Available as a free download from CadSoft, EAGLE is an easy to use software tool that can be enhanced with plug-ins — one of which is particularly important to using a CNC machine to create a PCB (we'll get to that in a bit). Before you commit to a commercial PCB order, it's a good idea to create a prototype of that PCB and the v90 makes this very simple. As a real-world example, we'll show a step-by-step on how to create the prototype of the Das BlinkenBoard from last month's column.

THE SCHEMATIC BONE'S CONNECTED TO THE ...

Here's a very quick overview of how we start with EAGLE and end up with a circuit board ready to solder up. We begin by drawing up the schematic in EAGLE. Then, we create the PCB by clicking the "board" icon (looks like two gates below the "View" icon in the tool bar. A pop-up message asking if we want to create the PCB from the schematic is presented, to which we answer yes.

EAGLE now creates an empty PCB with all the parts off to the left of the board. All connections are shown as yellow lines (which are elastic). As you move parts around, the lines stay connected.

Spend some time arranging the parts, trying to minimize crossing lines by rotating the parts. (TIP: Right-click while a part is selected and it will rotate 90 degrees with each click). Once you have a layout you like, it's time to auto-route the board. While there are a lot of parameters that can be set, we'll do this with the defaults. The auto route button is under Tools.

EAGLE auto-routes and (hopefully) shows 100% complete in the bottom left corner. If the board is too full or if the routing rules (a.k.a., Design Rule Checks) are too restrictive, your design may not route on the first try. It's fairly simple to see what needs your attention as un-routed traces will still be yellow. In our example here, the routing completed to 100%.

Even after the auto-route is complete, you may move some traces to suit your preferences using the four-arrow select tool on the left tool bar. For example, we increased the thickness of various traces where possible ("change width" using the wrench tool on the left tool bar).

ISOLATING — THE NEXT STEP

The next step involves the plug-in for EAGLE (also know as a ULP or User Language Program) I mentioned earlier. It's called PCB-GCODE and is a free download thanks to John Johnson at **pcbgcode.org** (see Resources). PCB-GCODE converts the EAGLE layout from a standard PCB layout to an "Isolation" type layout.

An "Isolation Route" is where we remove only enough copper to isolate the traces on the board from one another. This looks different than a normal PCB which only retains the necessary copper to make it work. As a plug-in for EAGLE, PCB-GCODE is a bit intricate to get going, but the following steps should be helpful.

To get PCB-GCODE started, download and install it on your Windows machine using the instructions included on the website. Once PCB-GCODE is installed, type "run" in the command line of EAGLE (**Figure 11**), then type "PCB." You should see "pcb-gcode_setup.ulp" and "pcb-gcode.ulp." Select the "pcb-gcode_setup.ulp"

RESOURCES

■ PROBOTIX Fireball v90 in December '08 issue
http://nutsvolts.texterity.com/nutsvolts/200812

■ PROBOTIX
www.PROBOTIX.com

■ PROBOTIX Fireball v90 at Maker Faire Austin
http://makerfaire.com/pub/e/2151

■ Measuring runout tutorial from PreciseBits.com
www.precisebits.com/tutorials/spindle_runout.htm

■ Software paths discussion
www.PROBOTIX.com/cnc_software

■ Fireball discussion boards:
www.FireballCNC.com
http://groups.yahoo.com/group/Fireballcnc

■ EAGLE from CadSoft:
www.cadsoft.de/freeware.htm

■ PCB-GCODE plug-in for EAGLE
http://pcbgcode.org

■ Vectric VCarve Pro
www.vectric.com

■ Das BlinkenBoard
www.DasBlinkenBoard.com

■ The Robot Group
www.TheRobotGroup.org

to run first (**Figure 12**).

Start in the Generation Options tab by changing the parameters to match the board thickness (milling depth), clearance minimums and maximums (isolation default/maximum), and the etching tool size (**Figure 13**). Remember to un-check the "Generate top outlines/drills" as we are doing a single-sided PCB with traces on the bottom.

Next up is the Machine tab. You can modify the parameters to match your CNC machine including Spin Up Time and Drill Dwell (in seconds), drill depth (I used 0.070" for 0.064" copper clad), and tool change position in x, y, and z (the CNC will move to this position for a tool change). The GCODE Style tab allows you to select the appropriate version; in our environment, we chose EMC for EMC2 under Linux.

After making these changes, choose "Accept and make my board." You should see a pop-up asking to run Windows' viewer (**Figure 14**). After accepting this, there should be a series of drawings, each followed by a "close this window" dialog box (**Figure 15**).

When done, the PCB-GCODE plug-in will generate etch, drill, and mill files, typically located in the "My Documents/Eagle" folder on your machine. The "etch" file contains the mechanical etching of traces and pads; the "drill" file contains the holes to be drilled; and the "mill" file contains the perimeter cut information for the finished board.

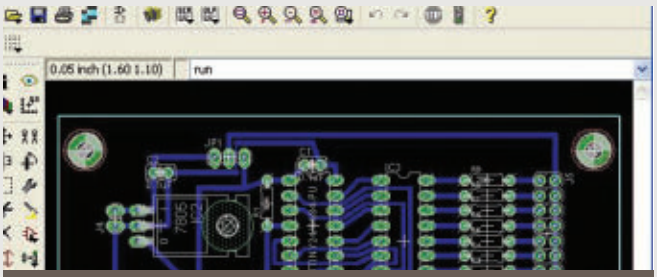
HERE THERE BE PENGUINS!

At this point in our environment, we simply copy the ".ngc" files to a "thumb drive" and take that over to the Linux machine we have connected to the Fireball v90. Once the files are copied, a few small changes need to be made before we start. First, the drill file has to be edited for tool changes. Look for lines that start with M06 and put everything from the semi-colon to the end of the line in parentheses. For example, this: "M06 T01 ; 0.0320" should become this: "M06 T01 (; 0.0320)" This change will make EMC2 stop and ask for a tool change.

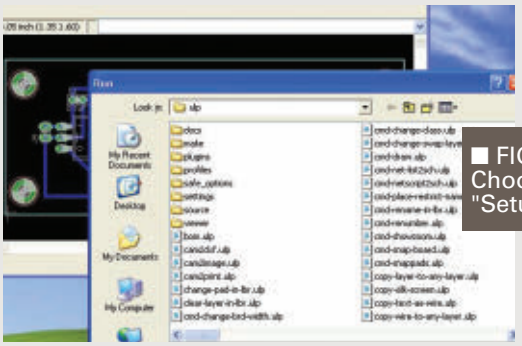
Setting the depth for PCB etching may be a bit tedious. Typically, you start with the z axis "zeroed" on the surface of the copper clad (this can be done by eye or by placing a small piece of paper under the bit and then owering the z axis until the paper is pinned. Then, back

A THANK YOU ... OR TWO ... OR MORE ...

I want to thank Paul Atkinson for all his help in preparing the material for this article and his wife Dolly for letting Paul come out and play (thanks for the pizza too!). Also, special thanks go out to Len Shelton of PROBOTIX for his unflagging dedication to the vision of home-CNC and his top-shelf customer support. Plus a quick shout-out to the guys at Precise Bits — you really know your stuff!

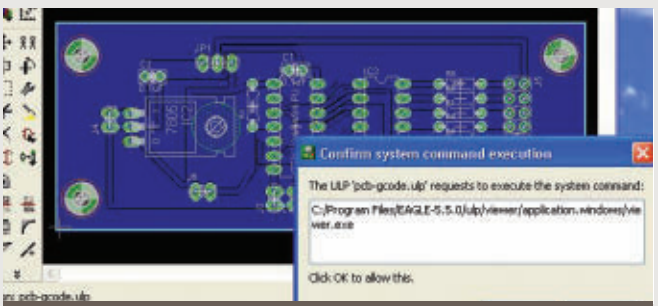


■ FIGURE 11. Type "RUN" in the command line on EAGLE to start PCB-GCODE.

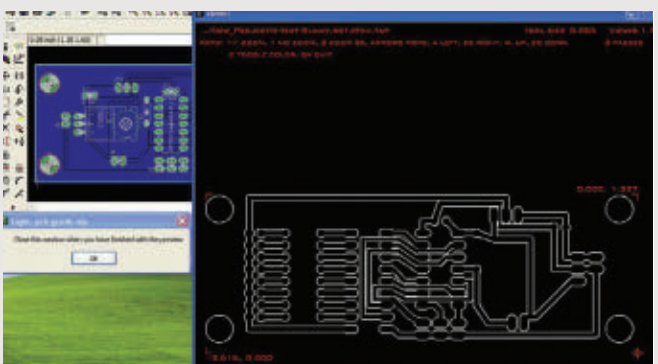


■ FIGURE 12. Choose the "Setup" file.

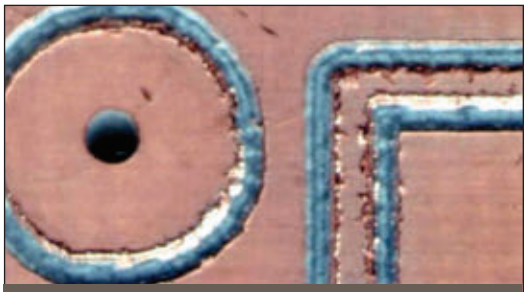
■ FIGURE 13. The Generation Options tab from PCB-GCODE.



■ FIGURE 14. PCB-GCODE prompts you to open the Windows Viewer to see the results.

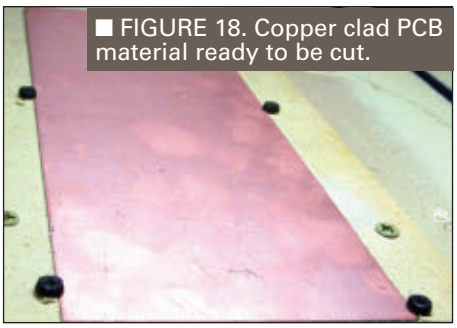


■ FIGURE 15. The trace isolation "etch" path generated by PCB-GCODE.

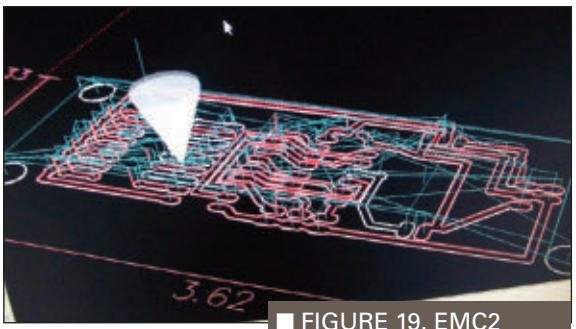


■ FIGURE 16. Test cut #1 shows the Z axis depth was too deep resulting in burred edges to the copper traces.

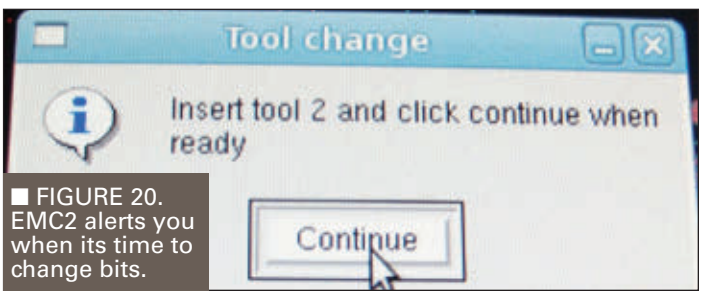
■ FIGURE 17. Test cut #2 shows the Z axis at the correct depth. Note the underlying PC board material is mostly intact.



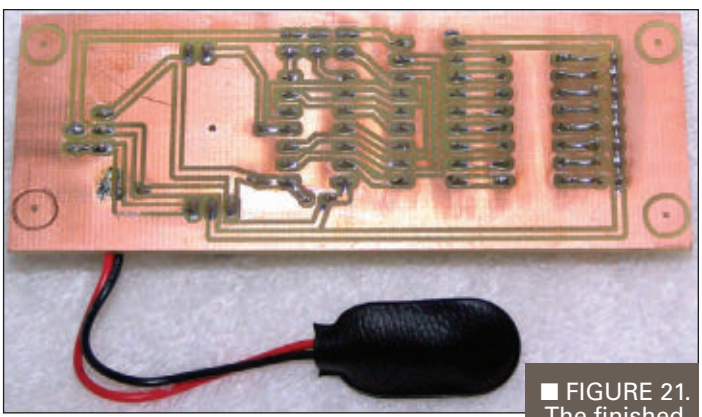
■ FIGURE 18. Copper clad PCB material ready to be cut.



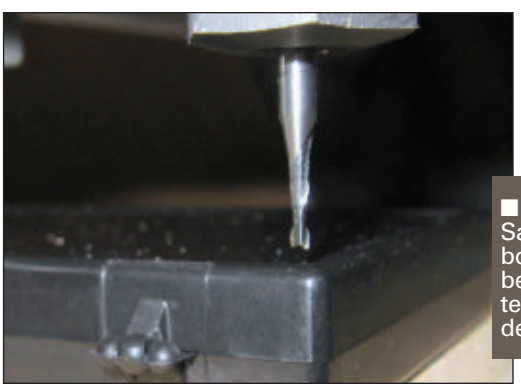
■ FIGURE 19. EMC2 running the etch pass on the v90.



■ FIGURE 20. EMC2 alerts you when its time to change bits.



■ FIGURE 21. The finished, working trace isolation version of Das Blinken Board!



■ FIGURE 22. Sacrificial plastic box ready to be test-cut for testing the bezel design.

the z axis off just enough to release the paper.

It's common to set the z axis a bit high since we can always go back and etch deeper a second time if needed. In the creation of the Das BlinkenBoard prototype, we actually did this "creeping down to copper" quite a few times to get it right. It's important to get this depth accurate because if you go too deep, the underlying board material is pulled up past the copper cladding resulting in a burred edge to the trace (**Figure 16**). When you get the depth set correctly, you will see evidence of the underlying board material being rubbed by the end of the bit, creating little circles in the path (**Figure 17**).

CUT IT OUT ALREADY

So, with our copper clad board mounted in place (**Figure 18**), it's just a matter of starting the run and keeping a close eye on the progress (**Figure 19**). (Note: Please use proper eye protection! The bit will throw debris!) Change the bits when asked (**Figure 20**) and then take your finished PCB and solder it up to see if it works (**Figure 21**). Ours did on the first try!

Now that we had success with the PCB creation, it was time to move on to cutting a case for Das BlinkenBoard. We used a similar process as that above, but since we didn't need to do the complex schematic and trace isolation work, we used VCarve Pro. We simply measured the various components and then layed out the holes/outlines for them. VCarve then created the GCODE and we used that same thumb drive to take it over to the v90 for cutting.

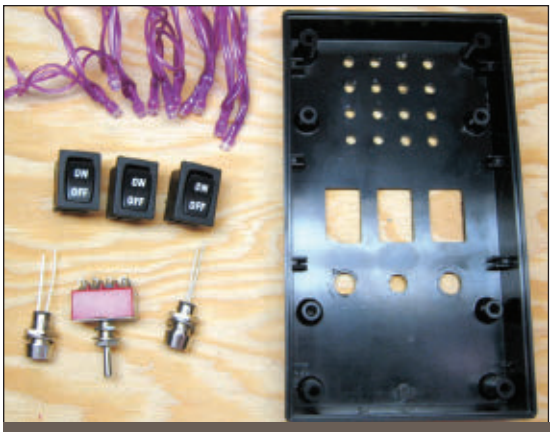
We placed a scrap piece of plastic in the CNC

DAS BLINKENBOARD UPDATE

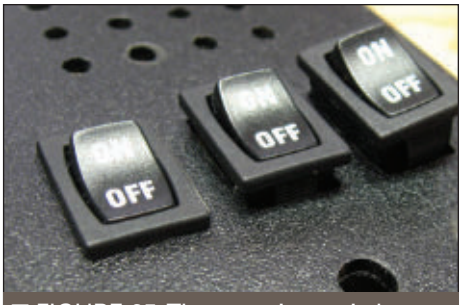
As I promised last month, some updated information has been posted on the Das BlinkenBoard website, including new software patterns focused on circular displays and a tutorial on how to reprogram the processor on the board using an inexpensive programming tool. Come by the website at **www.DasBlinkenBoard.com** and see what's new!

machine and did a quick test cut to be sure the orientation and fit were right (**Figure 22**), then placed a store-bought enclosure onto the CNC bed and cut out the component slots (**Figure 23**). After lining up all the components (**Figure 24**), we populated the holes beginning with the square snap-in switches (**Figure 25**), then the toggle switch, and lastly some LED holders (**Figure 26**). So now, Das BlinkenBoard has Das BlinkenBox (**Figure 27**)!

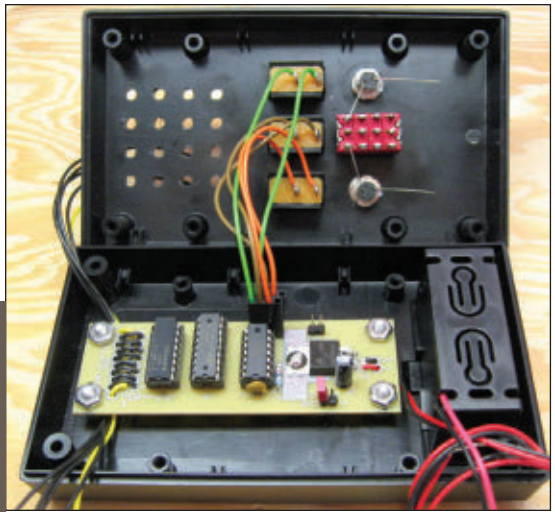
■ FIGURE 23. Finished front panel bezel for Das BlinkenBox.



■ FIGURE 24. Parts ready to go into the bezel.



■ FIGURE 25. The snap-ins switches shown here in various states of insertion.



■ FIGURE 26. All controls and most of the LEDs mounted in the bezel.

CUT! THAT'S A WRAP!

As you can see, besides cutting CD-ROM earrings it's quite possible to create your own professional-grade circuit boards and front panel bezels right in your own shop using a CNC machine. If you've been looking for an excuse to get into CNC systems, the time and money you'll save over mail-order PCB services, added to the frustration you'll save yourself over hand-fabricating your electronic enclosures, makes a CNC system pretty tempting! There are plenty of folks already involved in CNC and quite a few of them are ready to help out the new folks just starting out.

If you want to see some impressive things created by CNC owners, go by the PROBOTIX online forums and check out the pictures. As always, if you have any questions, feel free to drop me an email at vern@txis.com. **NV**

■ FIGURE 27. Das BlinkenBox front bezel with parts mounted.

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BY CHUCK HELLEBUYCK

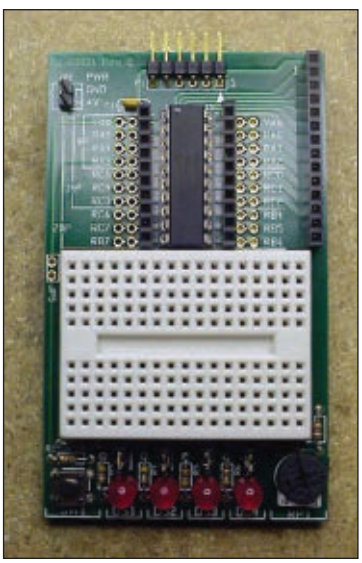
IMPROVING THE PICKIT 2 DEVELOPMENT BOARD

I've recommended the Microchip PICkit 2 Starter Kit for the projects in this column for quite a while, but along the way I improved the development board for my own projects. The one thing I always wanted to add was a breadboard area, so I modified the development board included with the Starter Kit — it's called the low pin count development board. I decided to use this board for all the projects in my next embedded C book (*Beginner's Guide to Embedded C Programming – Volume 2*) which I hope to have released by the time you read this. I've used this board in a few *Nuts & Volts* articles as well, but never explained how I built it. This month, I'll give you all the details to create your own version of this board.

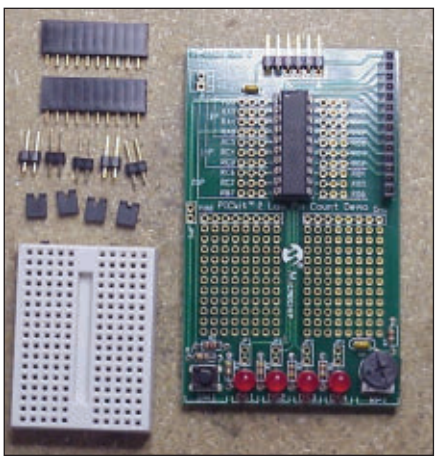
Figure 1 shows the completed board. Though it looks simple, this board is incredibly handy for developing code or sections of your larger projects. I also add a twist to this by showing how to create stackable versions, to make it easier to save your hardware for a later date.

GETTING STARTED

The parts required to build the development board are shown in **Figure 2**. The whole thing starts with the low pin count board and then I add one of the smallest breadboards I could find that happens to fit very nicely on the board. Additionally, the board has pads for adding jumpers in series with the LEDs. The board also has extra pads that connect to the 20-pin socket pins. This gives us access to the PIC16F690 microcontroller's I/O, but I wanted these to be socketed so I could just use jumper wires from those pads to the breadboard. A couple of 10-pin headers get that job done.



■ FIGURE 1. Finished development board.



■ FIGURE 2. PICkit 2 modification kit.

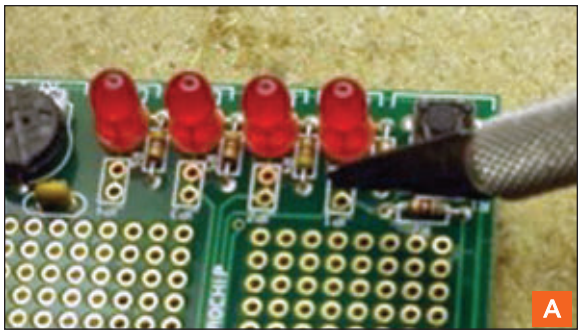
You can get these parts from various sources, but I got most of them through Jameco Electronics (**www.jameco.com**). The 10-pin female headers are actually 16-pin headers that I cut down to 10 pins with a side cutter. I lost one pin from the cut and ended up with a 10- and a five-pin header from that original 16-pin header.

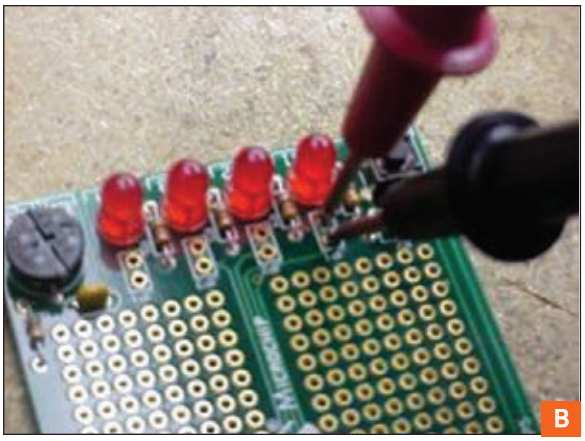
CONSTRUCTION

The first step I took was to cut the jumper bypass traces near the LEDs. I sliced the trace on both sides and then actually used a broken-tip X-ACTO knife to push forward and rip the isolated trace from the board (see **Figure 3A**). Next, I used an ohmmeter to verify that each trace was a successfully opened circuit (see **Figure 3B**). Once you solder the header in place, you can't get to the traces very easily. This is an important step that I learned the hard way. I actually had a small amount of trace still connected on one of the LEDs the first time I tried this, because I was too impatient to verify it with an ohmmeter.

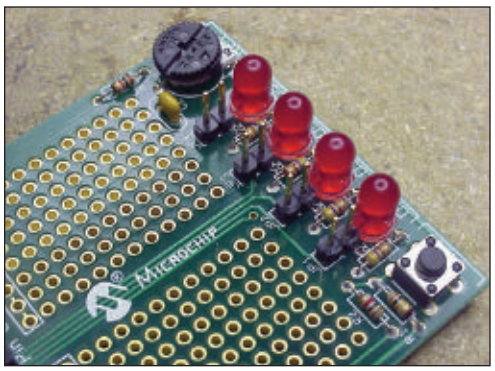
The next step is to solder the 2-pin headers in place. It is a little tricky to get these straight. You really need three hands to do this, but I

found that the height of the header was tall enough that I could install it and then flip the board over so the weight of the board held the header in place. I soldered one pin at a time and could see they were not exactly straight. Because I only soldered one side, I could heat the solder with one hand on the soldering iron and straighten the pins with the other hand by touching the second unsoldered cold pin. When I got the pin to where I wanted it, I let the solder cool and held it in place. When all the headers were straight, I went back and finished soldering the second pin. **Figures 4** and **5** illustrate this. If you look at the **schematic** for the demo board, you will see a jumper 5 that feeds power to the switch and the potentiometer. You could add a jumper to that connection in the same way we did with the LEDs, but I never needed that so I left them connected. Instead, I added a 2-pin header to the power connection shown in **Figure 6**. This enabled me to easily connect a battery pack to the board for external power.

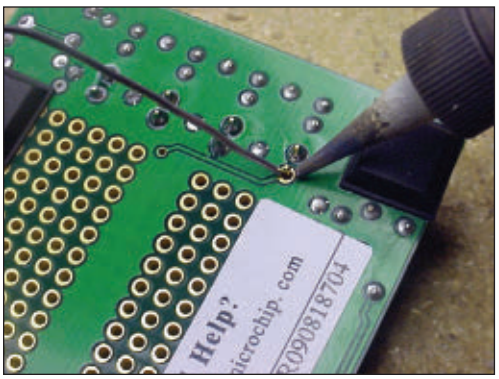




■ FIGURE 3A and 3B. Cutting Traces.



■ FIGURE 4. Header pins positioned straightly.



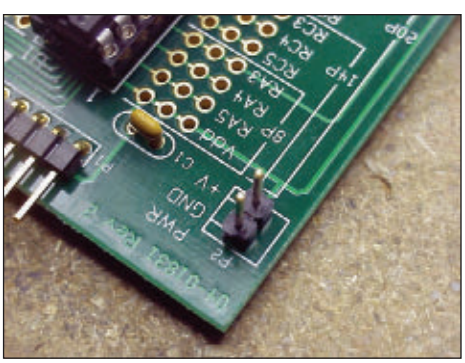
■ FIGURE 5. Final soldering of headers.

There are battery modules with built-in step-up regulators that give you a 5V output with a single AA battery. They connect nicely to the board. **Figure 7** shows the battery holder I refer to. I used one in the golf cart project from my May '09 column.

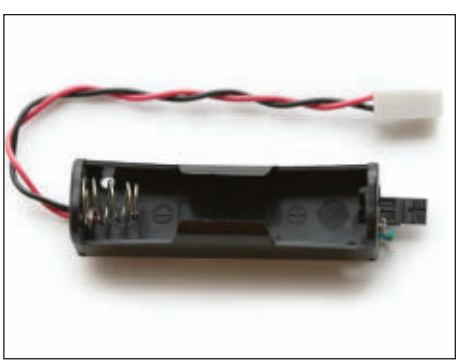
The 10-pin headers are the next item to install. I did the same trick of installing them and then flipping the board over to hold it while I soldered one pin. **Figure 8** shows the first header installed.

I could have placed the header in any one of the three positions next to the 20-pin socket but this seemed like a good spot since I would later be plugging in a stacking board, which I'll describe in a little bit. I added the second 10-pin header and then moved on to placing the breadboard.

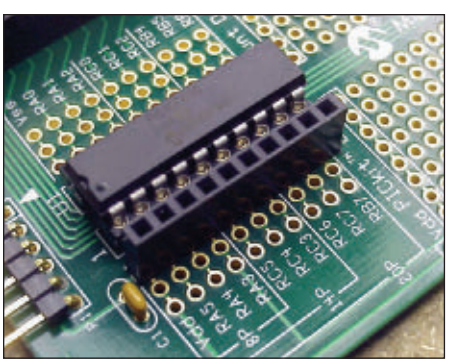
Figure 9 shows that the small breadboard has a double-sided tape backing that just requires you to peel off the protection layer. Before I removed the layer, however, I practiced placing the breadboard on the circuit board to make sure it would fit. The capacitor just above the potentiometer may need to be bent back a little to make it fit properly. Once you are ready, peel the backing and stick it to the board (see **Figure 10**). The double-sided tape holds well, so it isn't going to budge



■ FIGURE 6. Power connection.

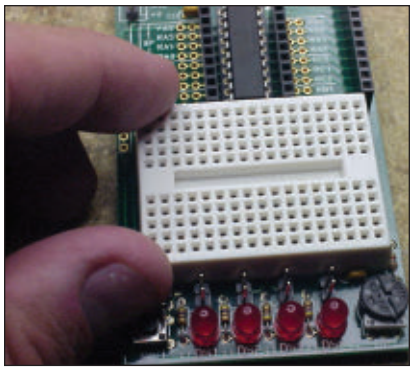


■ FIGURE 7. AA battery holder with 5V step-up circuitry.

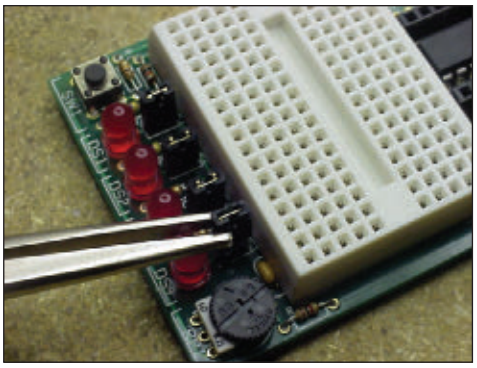


■ FIGURE 8. 10-pin header installed.

■ FIGURE 9. Breadboard double-sided tape backing.



■ FIGURE 10. Placing the Breadboard.



■ FIGURE 11. Shorting Blocks Installed.

after you get it into place.

The final step is to install the shorting blocks to the two-pin LED headers. This can be a little tight for big fingers, so I used needle-nose pliers (see **Figure 11**). When you want to disconnect the LEDs, place the shorting blocks sideways on just one pin so they stay with the board but don't complete the connection. The shorting blocks stay tight enough on one pin to not fall off.

We now have the board shown in Figure 1 completed and ready for development. There is one problem I found, though. Once I built a project on the breadboard area to save it for later, I either had to build another board like this or disconnect all the wires and start the new project. More of these boards are available for a very reasonable price from **www.microchipdirect.com** or other suppliers such as Digi-Key, under part # DM164120-1.

As an alternative to creating a whole new board, I decided to stack them instead. Many years ago, I developed this concept for a very complicated and expensive development board with lots of added features. My solution was to create a stacking board that contained only a breadboard area, with a header to connect to the other circuitry. This allowed me to simply plug in a new board and unplug the project when I was done. I decided to try that here with one of the blank low pin count demo boards. **Figure 12** shows the final board being stacked on top of the board I just built.

STACKER BOARD

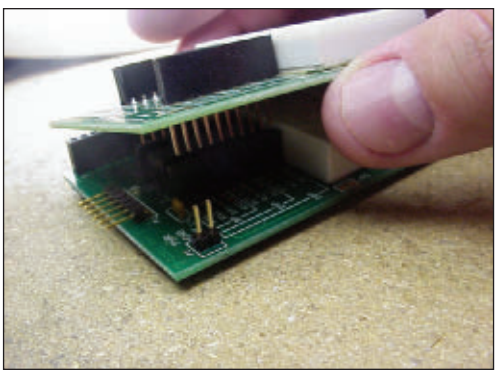
To create the stacker board, I used some of the same parts, but this time started with the blank board shown in **Figure 13**. Also, I added 10-pin male headers instead of two-pin headers to the collection.

The first step is to solder the 10-pin male headers to the bottom of the board, as shown in **Figure 14**. The male headers should be in the same row as the 20-pin female headers we installed on the completed development board.

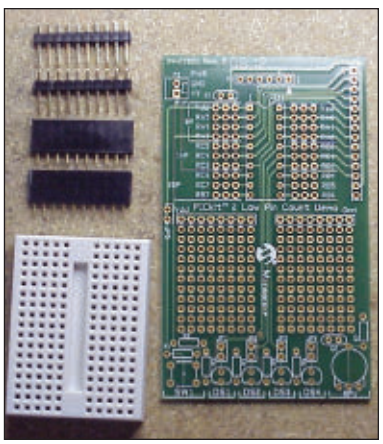
Next, flip the board over and solder the 10-pin female headers next to the male headers. I used the same method again of soldering one pin, to allow me to straighten them. **Figure 15** shows the result.

The final step is to install another breadboard (see **Figure 16**) to this blank board. You don't have to worry about squeezing it in because of the open space. If you want to add the other components you can, but they will be connected in parallel with the components underneath on the main development board.

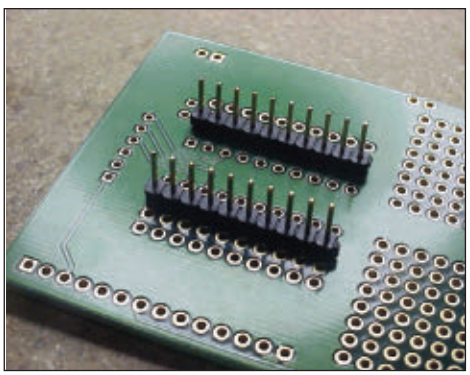
Figure 17 shows how — when the stacker is installed — the PIC16F690 is cleared, as are the programming pins that connect to the PICkit 2 programmer. This is a lower-cost way to build multiple projects and



■ FIGURE 12. Stacking the boards.



■ FIGURE 13. Stacker board parts.



■ FIGURE 14. Headers installed on bottom of board.

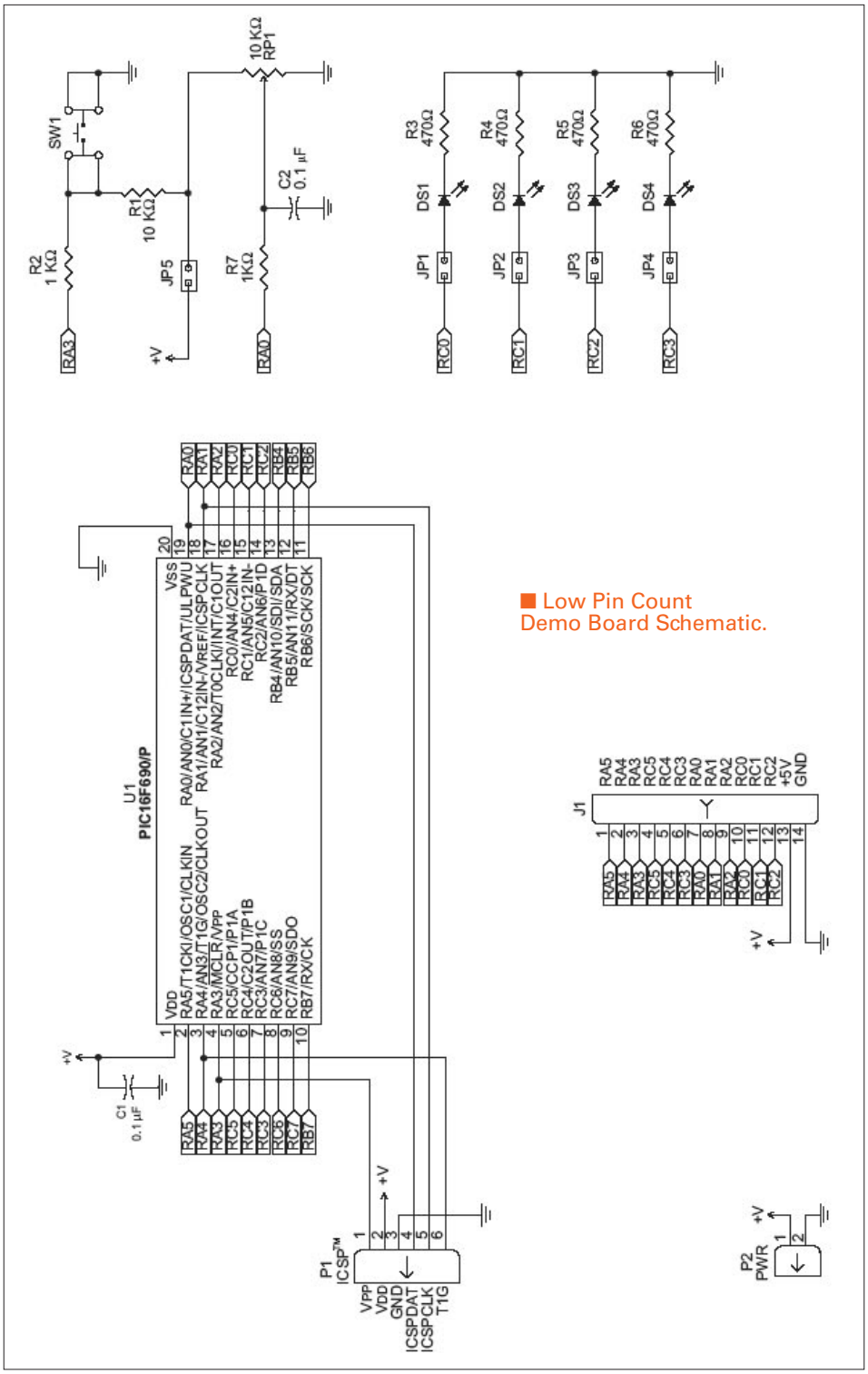
save them onto a removable board.

CONCLUSION

This development board can be used in many different ways. I found the breadboard to be extremely useful, despite its small size. It was large enough to plug in a parallel LCD with a 14-pin header and still have room for other connections. You'll see more of this board in future columns. I really like the way it turned out.

There are other PICkit 2 development boards, but the 18- and 20-pin were the only ones this worked on. The 28-pin board doesn't have enough open space and the surface-mount boards with 44-pin parts have an open area that is too short. Maybe I'll create my own 28-pin board since I find the 28-pin parts very handy for developing. They have all the extra I/O that allows access to more features of the PIC. A PIC16F886 is a great part to develop with, though the sample version of microEngineering Labs' PICBASIC PRO compiler doesn't support that part. You have to use the 28-pin PIC16F87X family, instead.

Speaking of the PICBASIC PRO compiler, it is being updated to work with version 8.20 or later of the MPLAB IDE. The MPLAB IDE version 8.20 and later no longer support a .cod file that the PICBASIC PRO relies on. Therefore, use MPLAB IDE version 8.15 to run the current PICBASIC PRO compiler. Some people have asked me about using the new PICkit 3 programmer released by Microchip. The problem is the PICkit 3 programmer requires MPLAB 8.20 to run, so we have a mismatch. Until the PICBASIC PRO compiler can run on version 8.20 or later, they won't work together. The PICkit 3 programmer also doesn't have a command-line option to run in the PICBASIC PRO MCStudio IDE, so that isn't an alternative. As soon as all this gets sorted out, I will cover the PICkit 3 programmer here, because it is a great higher-speed programmer upgrade when compared to the PICkit 2. If you program in C using the HI-TECH C Pro compiler, then the PICkit 3 will work great for you. In fact, Microchip recently bought HI-TECH Software, so the compiler is now a Microchip product. The compiler comes in various versions for the



■ Low Pin Count Demo Board Schematic.

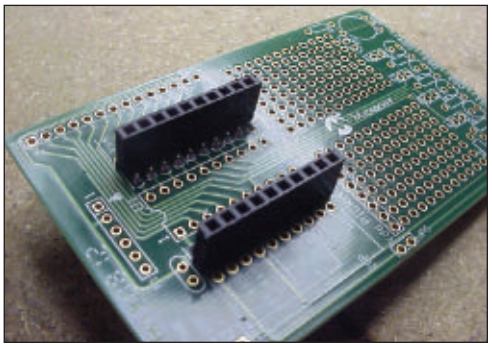
PARTS LIST

Qty.	Description	Part Number/Supplier
1	Small Breadboard	923273-ND/Digi-Key
4	Shorting Blocks	22023/Jameco
5	2-Pin 0.1" Single Row Header	222966/Jameco
2	16-Pin 0.1" Female Header (cut to 10 pins)	308592/Jameco

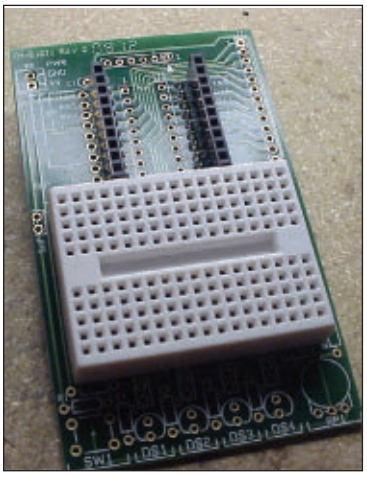
different PIC families, including a version that supports all of the PIC10F/12F/16F parts. That version of compiler will automatically install when you install the latest version of the MPLAB IDE. I use the HI-TECH C Pro compiler in all of my embedded C books and projects.

The HI-TECH C Pro compiler has a great optimization feature called Omniscient Code Generation, which allows you to fit more code into a smaller part. Most hobbyists, however, probably don't need that code optimization, so you have the option to run it in Lite mode without any restrictions other than the code will take up more space than an optimized version. Best of all, the compiler is free if you run in this mode. For the person just getting started with PICs and C, this is a great compiler option. If you decide to move to the C programming language and need a little help getting over that beginner's hump, check out my book *Beginner's Guide to Embedded C Programming* and then my follow-up book *Beginner's Guide to Embedded C Programming – Volume 2* which covers timers, interrupts, communication, displays, and more. Both books use this free Lite version of the HI-TECH C Pro compiler. My books are available through the *Nuts & Volts* webstore at **http://store.nutsvolts.com**.

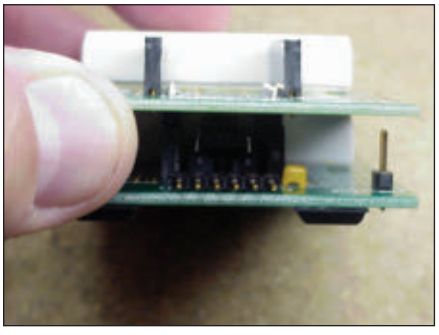
Until then, shoot me an email for article/project ideas to chuck@elproducts.com. I try to read them all. **NV**



■ FIGURE 15. 10-pin Female Headers Installed.



■ FIGURE 16. Final Stack Board.



■ FIGURE 17. PIC16F690 Shown Under the Stacker Board.

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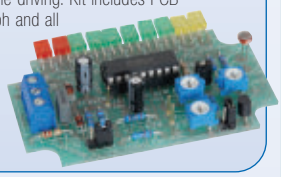

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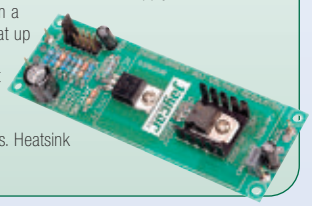

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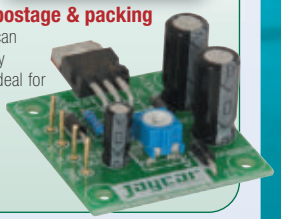

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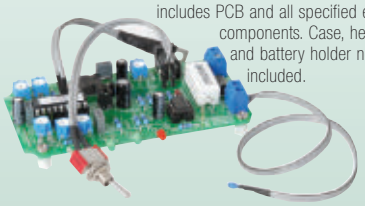

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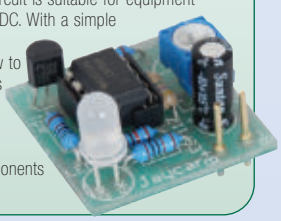
KA-1778 $6.00 plus postage & packing

This tiny circuit measures just 25 x 25mm and will provide power indication and low voltage indication using a bi-color LED, and can be used in just about any piece of battery operated equipment. Current consumption is only 3mA at 6V and 8mA at 10V and the circuit is suitable for equipment powered from about 6-30VDC. With a simple circuit change, the bi-color LED will produce a red glow to indicate that the voltage has EXCEEDED a preset value.



- PCB, bi-color LED and all specified electronic components supplied.

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BY FRED EADY

KIDS CAN LOVE ENGINEERING!

DO YOU REMEMBER WHO WAS RESPONSIBLE FOR YOUR INITIAL INTEREST IN ELECTRONICS? I do. His name was Leslie Armos. Mr. Armos was from Poland and worked as an electrical engineer at Redstone Arsenal in Huntsville, AL. I can still see (and hear) those magnificent high fidelity tube amplifiers Mr. Armos built from scratch. In fact, Mr. Armos custom-built one for my father which eventually became my first personal electronic "domain." Between playing my Supremes and Temptations records (yes, records) loud on Mr. Armos's homemade stereo equipment, I was under the tutelage of Mr. Armos learning transistor and tube circuit basics. Heavy involvement in electronics of all kinds was obviously my destiny.

After Mr. Armos passed away, I was taken under the wing of yet another Redstone Arsenal rocket engineer, Pressley Fife. Mr. Fife worked as the Sunday morning engineer at WEKR in Fayetteville, TN. Depending on my Saturday night, Mr. Fife would keep me awake during my early Sunday morning shift while teaching me advanced transistor theory and logic. The station owner later told me that Mr. Fife was the man that strapped the first chimp astronaut (HAM) into its Mercury capsule.

Mr. Armos and Mr. Fife were very important people in my life. Every year, Lockheed Martin sponsors Space Day at select Florida elementary schools. I participate in the Sarasota Space Day and attempt to become a Leslie Armos or Pressley Fife to the 190 or so students that pass through my science station. This year's science station consisted of a Lenovo NetBook coupled to a USB-to-CAN bridge. The goal was to introduce the students to a working network they could actually see and touch.

Once the students connected the network cables, they could use the Lenovo NetBook Visual Basic interface to flash each other's station LEDs, spin a trio of motors attached to the network, and "text" each other's stations. Although remotely spinning motors was fun for all, it was most interesting to note that every grade level (1-5) was thrilled to find out they could text each other. I witnessed first graders texting using full sentences!

Exposing the students to electronic nomenclature and raw electronic parts was the idea behind my science station. While the application was aimed at elementary students, the technology behind the application may be of interest to you.

Let's begin by examining the Lenovo NetBook application, which relies heavily on a programming tool from MarshallSoft.

WSC4VB

Nope. WSC4VB is not some texting shorthand sent by those smart little first graders. WSC4VB is short for Windows Standard Serial Communications for Visual Basic. WSC4VB is a toolkit that allows for easy and reliable construction of serial communications-based Visual Basic applications. The Windows Standard Serial Communications Library is actually a component DLL library which uses the Windows API (Application Programmer's Interface) to communicate with devices attached to the PC's serial port.

I accessed the Communications Library by way of the Visual Basic component of Microsoft Visual Studio 2008. WSC4VB works with the old stuff (Visual Basic 3.0-Visual Basic 6.0) and the new stuff (Microsoft Visual Studio .NET Framework). WSC4VB can also be used to support communications sessions within any VBA (Visual Basic for Applications) language. For those of you that haven't dabbled with VBA, access is included in Excel, Access, and MS Office.

The Lenovo NetBook comes standard with Windows XP Home. However, WSC4VB's toolkit will run on every Windows platform from Windows 95 to Vista. The reason for its diverse operating system compatibility lies in the fact that WSC4VB can be accessed from a standard Windows 16-bit DLL (WSC16.DLL) or 32-bit DLL (WSC32.DLL), both of which are part

of the WSC4VB package.

THE SPACE DAY APPLICATION

I rolled WSC4VB into the Space Day Visual Basic application to eliminate the need for mechanical pushbutton switches on the network nodes. The ability to use Visual Basic controls (text areas, buttons, etc.) in conjunction with WSC4VB API calls also allowed me to tailor the user interface to my elementary school audience. The Space Day NetBook Visual Basic interface you see in **Screenshot 1** was obvious to the most casual first grade observer. The students were divided into three teams upon entering the lab. After I pointed out the LEDs and motors on the CAN network nodes, there were no questions as to how to use the Visual Basic interface or Lenovo NetBook that sat before them.

ADDRESSING THE CAN NODES

The Visual Basic code behind each button is rather simple. Visual Basic is an event driven environment which depends on timer events, program events, and user-generated events as cues to perform a task. For instance, here's the code behind the SEND TO TEAM X buttons:

```
Private Sub btnTEAM1_Click(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles btnTEAM1.Click
    Dim Code As Integer
    Code = SioPutc(ComPort, &H1)
    Call DisplayLine("Send To TEAM 1 ->")
    dest_addr = 1
End Sub

Private Sub btnTEAM2_Click(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles btnTEAM2.Click
    Dim Code As Integer
    Code = SioPutc(ComPort, &H2)
    Call DisplayLine("Send To TEAM 2 ->")
    dest_addr = 2
End Sub

Private Sub btnTEAM3_Click(ByVal sender
As System.Object, ByVal e As
System.EventArgs) Handles
btnTEAM3.Click
    Dim Code As Integer
    Code = SioPutc(ComPort, &H3)
    Call DisplayLine("Send To TEAM 3 -
>")
    dest_addr = 3
End Sub
```

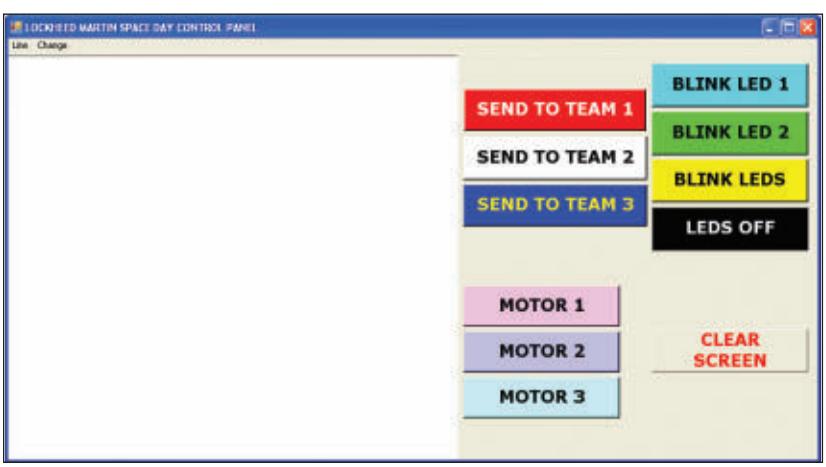
Our coding work begins with the Visual Basic *Dim* statement as the next WSC4VB call returns an integer. *SioPutc* is a WSC4VB function that copies a character to the transmit queue for transmission by the PC's UART. As you can see, clicking on the SEND TO TEAM 1 button sends a hexadecimal 0x01 to the UART. The *DisplayLine* subroutine is not a WSC4VB function and looks like this:

```
Private Sub DisplayLine(ByVal X As String)
    Message.Text = Message.Text + X +
        Chr(13) + Chr(10)
    LineNumber = LineNumber + 1
End Sub
```

Message is the large Visual Basic text area control that takes up all of the left of the control panel layout. The argument string in the *DisplayLine* function plus a carriage return (Chr(13)) and line feed (Chr(10)) are appended to any existing string that is being displayed in the *Message* control window.

The *dest_addr* variable is declared as an integer and is used to help make status display decisions like this:

```
Private Sub btnBLINKLED1_Click(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles btnBLINKLED1.Click
    Dim Code As Integer
    Code = SioPutc(ComPort, &H4)
    Select Case dest_addr
        Case 1
            Call DisplayLine("Sent Blink LED 1
                Command To TEAM 1")
        Case 2
            Call DisplayLine("Sent Blink LED 1
                Command To TEAM 2")
        Case 3
            Call DisplayLine("Sent Blink LED 1
                Command To TEAM 3")
    End Select
End Sub
```



■ SCREENSHOT 1. Nothing fancy here as far as Visual Basic goes. The buttons are standard Visual Basic button controls and the large window on the left is a standard Visual Basic text message control. All of the difficult stuff behind the scenes is done by WSC4VB.

The SEND TO TEAM 1, 2, and 3 functions send a hexadecimal 0x01, 0x02, and 0x03, respectively. Upon power-up or reset, the PIC18F4680 firmware for each of the three nodes hardcodes a unique CAN hardware address (0xA1, 0xA2, 0xA3) to each node. Thus, sending a 0x01 sets the PIC18F4680 node's CAN destination address to 0xA1. Any incoming serial command from the Visual Basic application that follows is sent to CAN address 0xA1. Here's a code snippet that represents the Visual Basic application instructing the PIC18F4680-based node to set its CAN destination address to 0xA1:

```
#define addr_team1   0xA1
#define addr_team2   0xA2
#define addr_team3   0xA3

char lcdmsg_sendto[] = "SEND TO ";
char lcdmsg_team1[] = " TEAM 1 ";
//***********************************************
//* VISUAL BASIC SERIAL CHARACTER SERVICE LOOP
//***********************************************

if( CharInQueue() )
    {
       bytein = recvchar();
       switch(bytein)
       {
           case 0x01:
               dest_addr = addr_team1;
               lcdcls;
               line1;
               for(m8=0;m8<8;++m8)
                      lcd_send_byte(1,
                        lcdmsg_sendto[m8]);
               line2;
               for(m8=0;m8<8;++m8)
                      lcd_send_byte(1,
                        lcdmsg_team1[m8]);
           break;
```

Each node also has an LCD that is used to display status information. As you can see in the PIC18F4680 code snippet we just examined, the LCD will display "SEND TO TEAM 1" upon receiving a hexadecimal 0x01 from the Visual Basic application. This works the same for all three nodes. It's logical to deduce that replacing the *bytein* variable with 0x02 will target CAN address 0xA2 and display "SEND TO TEAM 2" on the node's LCD. Now that we know that the CAN destination addresses are set by the SEND TO TEAM X buttons, let's explore what happens when we click on the BLINK LED 1 button.

EXERCISING THE LEDS

Backtracking to the *btnBLINKLED1_Click* subroutine code snippet, we see that a hexadecimal 0x04 is sent serially to the locally attached CAN node. If the destination address has been set to the attached CAN node's address, the LED command will act on the local CAN node and no CAN message will be sent over the network. On the other hand, if the destination address belongs to a remote CAN node, a CAN message will be generated to send the LED command to the remote node. The local LCD reflects the result of the LED command:

```
//***********************************************
//* VISUAL BASIC SERIAL CHARACTER SERVICE LOOP
//***********************************************
if( CharInQueue() )
    {
       bytein = recvchar();
       switch(bytein)
       {
         case 0x01:  //assign dest addr = 0xA1
         case 0x02:
         case 0x03:
          ~~~~~~~~~~~~~~~~~~
          case 0x04:
          if(my_addr == dest_addr) //blink LED 1
          {
              clr_flags();
              led2_off;
              flags.blink1 = 1;
          line1;
          for(m8=0;m8<8;++m8)
              lcd_send_byte(1,lcdmsg_1is[m8]);
          line2;
          for(m8=0;m8<8;++m8)
              lcd_send_byte(1,
                lcdmsg_blinking[m8]);
          }
          else       //blink remote LED 1
          {
              send_can_msg2(dest_addr,cblink1);
              line1;
              for(m8=0;m8<8;++m8)
                     lcd_send_byte(1,
                       lcdmsg_sent[m8]);
              line2;
              for(m8=0;m8<8;++m8)
                     lcd_send_byte(1,
                       lcdmsg_blink1[m8]);
          }
       break;
```

The *btnBLINKLED2_Click* subroutine sends a hexadecimal 0x05 and the PIC firmware on the attached CAN node executes the *case 0x05* switch statements; these are identical to the *case 0x04* statements with LED 2 replacing LED 1 as the focal point.

I have provided both the Visual Basic and PIC18F4680 source code for you via the *Nuts & Volts* website at **www.nutsvolts.com**. If you examine the source code sets, you'll find that you can easily track a Visual

Basic button event all the way through the PIC18F4680 code. For instance, clicking on the BLINK LEDS button will send a hexadecimal 0x06. All you have to do is navigate to the VISUAL BASIC SERIAL CHARACTER SERVICE LOOP area of the PIC18F4680 code and follow the *case 0x06* switch statements. If the *case* statement you are following issues a CAN message to a destination address, you can follow the thread by selecting the appropriate *case* statement in the CAN SERVICE LOOP area of the PIC code. Let's follow the *send_can_msg2 (dest_addr,cblink1)*; trail:

```
//***********************************************
//* CAN SERVICE LOOP
//***********************************************
    do{
        if(ECANReceiveMessage(&id, data,
         &dataLen, &canflags) )
        {
            if (data[0] == my_addr)
            {
                switch(data[1]) {
                    case cblink1:
                        clr_flags();
                        led2_off;
                        flags.blink1 = 1;
                        lcdcls;
                        line1;
                        for(m8=0;m8<8;++m8)
                            lcd_send_byte(1,
                              lcdmsg_1is[m8]);
                        line2;
                        for(m8=0;m8<8;++m8)
                            lcd_send_byte(1,
                              lcdmsg_blinking[m8]);
                        break;
```

It's easy to see that I've keyed on the *cblink1* case statement. The receiving node extinguishes LED 2 and enables the blinking of LED 1 while posting the status of LED 1 on the local LCD.

Let's recap the chain of events following a Visual Basic button click:

1. A transmission control character (0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07) representing an LED command is sent serially via USB to the local CAN node.
2. If the destination address matches the destination address held by the local CAN node, the local CAN node acts on the incoming command.
3. If the destination address is not local, the command is forwarded via CAN to the remote destination address where the task is ultimately performed.

Note that transmission control characters for null (0x00), carriage return (0x0D), and line feed (0x0A) are not used in the command sequences for obvious reasons.

Controlling the trio of motors is just as easy and straightforward as blinking LEDs. Let's take a quick look at the Visual Basic code and how the PIC on the motor node reacts to it.

SPINNING MOTORS

From the Visual Basic perspective, motor commands are no more complicated than their LED counterparts. In fact, motor commands are parsed and routed exactly like the LED commands. This Visual Basic motor command code should look very familiar:

```
Private Sub btnMOTOR1_Click(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles btnMOTOR1.Click
       Dim Code As Integer
       Code = SioPutc(ComPort, &H8)
       Call DisplayLine("Sent Power Command to
                              MOTOR 1")
End Sub

Private Sub btnMOTOR2_Click(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles btnMOTOR2.Click
       Dim Code As Integer
       Code = SioPutc(ComPort, &H9)
       Call DisplayLine("Sent Power Command to
                               MOTOR 2")
End Sub

Private Sub btnMOTOR3_Click(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles btnMOTOR3.Click
       Dim Code As Integer
       Code = SioPutc(ComPort, &HB)
       Call DisplayLine("Sent Power Command to
                              MOTOR 3")
End Sub
```

The PIC18F6680 code is just as easily understood. Every motor command that is processed by the PIC18F6680 is delivered via CAN. The motor node has a CAN address of 0xA0. Depending on the state of the rotation flags (stat.fwdx, stat.revx, stat.haltx), clicking on any MOTOR button will cause the addressed motor to spin clockwise, counterclockwise, or stop, respectively. With the exception of the motor specific flags, the motor control *case* statements are identical for all three motors. For instance, *motor(1,cw)* will spin MOTOR 1 in a clockwise direction. Issuing *motor(2,cw)* will spin MOTOR 2 in a clockwise direction. Here's the code snippet that handles MOTOR 1:

```
    do{

if(ECANReceiveMessage(&id, data,
    &dataLen &canflags))
```

```
{
    if (data[0] == my_addr)
    {
        switch(data[1]) {
            case cmtr1:
                if(stat.halt1){
                    motor(1,cw);
                }
                else if(stat.fwd1) {
                    motor(1,stop);
                    mdelay1(100);
                    motor(1,ccw);
                }
                else if(stat.rev1) {
                    motor(1,stop);
                }
                break;
```

Replace the "1s" with a "2" and you have the control code for MOTOR 2. The same idea goes for MOTOR 3. The complete motor code source is also included in the download package. There's just enough code to initialize the PIC, send CAN messages, and control the rotation of the motors. So, you shouldn't have any problems following the flow of the motor control code.

TEXTING OVER CAN

The CAN texting is in the Stone Age when compared to modern day cell phone texting. However, the students still had a blast with it. The Visual Basic code is very simple. Every 250 ms, the Visual Basic application checks to see if a valid character has been retrieved from the PC's UART. If one is available, it simply gets displayed in the Message control window. Naturally, WSC4VB calls do the heavy lifting. And to think, I almost didn't include the timed receive code you see here in the science station application:

```
    Sub GetIncoming()
        Dim I As Integer
        Dim TheChar As Integer
        For I = 1 To 1000
            TheChar = SioGetc(ComPort)
            If TheChar > 0 Then
                Call DisplayString(Chr(TheChar))
            Else
                Exit For
            End If
        Next I
    End Sub

Private Sub Timer1_Tick(ByVal sender As
System.Object, ByVal e As System.EventArgs)
Handles Timer1.Tick
    Dim Code As Integer
    Const EV_RXCHAR = &H1   ' Any Char received
    If OnLineFlag Then
        ' turn timer off
        Timer1.Enabled = False
        'get (and display) all serial data
        Call GetIncoming()
        ' block (efficiently wait) until
        ' there is more data available
        Code = SioEventWait(ComPort,
            EV_RXCHAR, 250)
        ' re-enable timer
        Timer1.Interval = 1
        Timer1.Enabled = True
        End If
    End Sub
```

That does it for the Visual Basic and PIC application code. So, let's look at the hardware that supports the science station application.

THE USB-TO-CAN BRIDGE NODES

As you already know, the Visual Basic application needs to communicate serially with the local CAN node. So, USB is the only way to go in that the Lenovo NetBooks don't have standard nine-pin serial ports. The extra value of using USB is that I can eliminate the CAN node power supply circuitry and power the CAN nodes from their USB hosts. The CAN node you see in **Photo 1** has the distinction of being powered by USB.

If you've had the time to keep up with recent Design Cycle discussions, the USB circuitry in **Schematic 1** should look familiar. The CAN node USB interface is a classic implementation of the Silicon Laboratories CP2102 USB-to-UART bridge, which we discussed at length in a previous Design Cycle installment. The CP2102 is

SOURCES

MarshallSoft Computing, Inc.
www.marshallsoft.com
WSC4VB

Microsoft — www.microsoft.com
Microsoft Visual Studio 2008

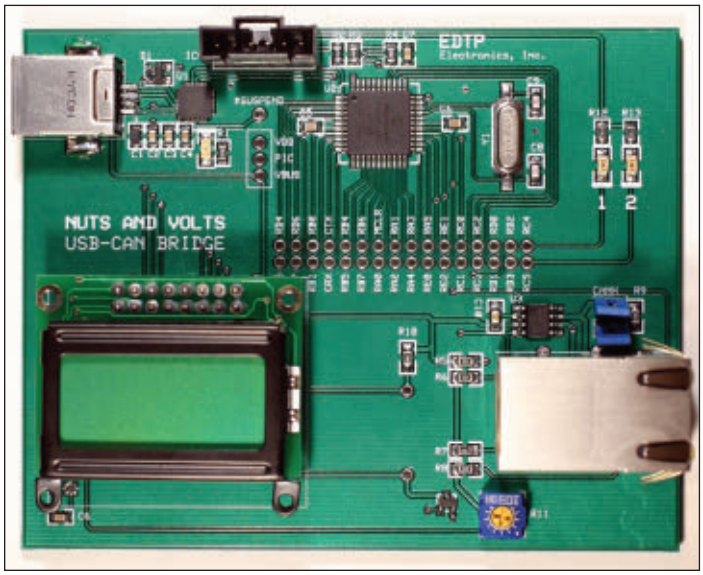
Microchip — www.microchip.com
PIC18F4680
PIC18F6680
MCP2551

Silicon Laboratories — www.silabs.com
CP2102

Lenovo — www.lenovo.com
Lenovo S10 IdeaPad NetBook

The printed circuit board for this project can be obtained from ExpressPCB at **www.expresspcb.com**.

The PIC18F4680 and PIC18F6680 code was compiled with the HI-TECH PICC-18 C compiler.



■ PHOTO 1. The heart of this design is the PIC18F4680, which is CAN capable. A CP2102 USB-to-UART bridge interfaces the Lenovo NetBook's USB interface to the PIC. The MCP2551 CAN transceiver is performing the network interface duty. You can't see it in this shot, but the CAN physical interface is a stacked set of eight-pin RJ-45 female connectors with integral LED indicators.

supported on the PC by serial port emulation drivers provided by Silicon Laboratories. WSC4VB has the ability to communicate using the CP2102 drivers which allows the Visual Basic application code to see the CP2102 as a standard COM port.

With the exception of the CAN engine interface, the PIC18F4680 is pin-compatible with the PIC18F4620. That means we can reuse LCD driver firmware that was written for a PIC18F4620 or PIC18F2620. I just happen to have some PIC18F2620 LCD driver firmware we can put to use here. The LCD driver source code is included in the source code download package associated with this month's Design Cycle column.

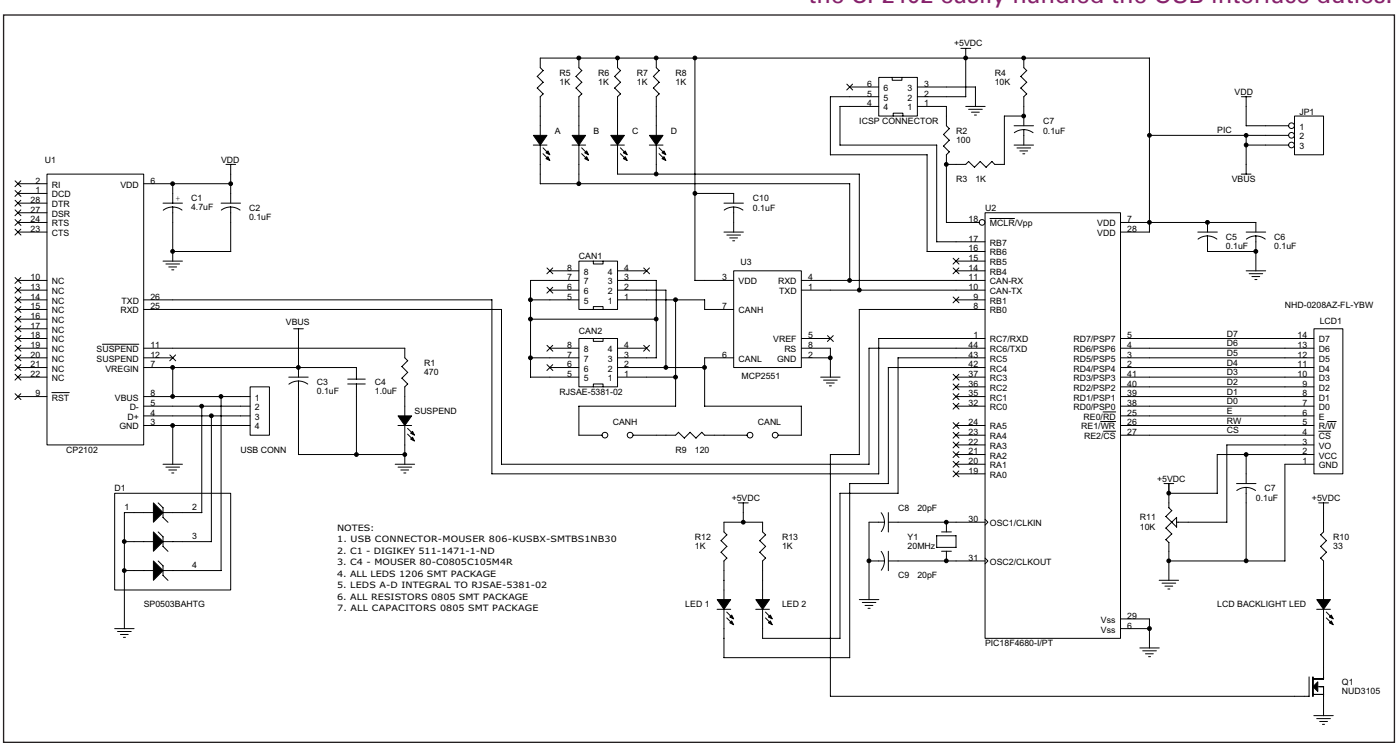
The PIC18F4680's physical CAN interface is provided by a Microchip MCP2551 high speed CAN transceiver. The CANH and CANL jumpers are termination jumpers and should only be installed at the end nodes of the network. When both jumpers are installed, the 120Ω termination resistor will be electrically placed across the CANH and CANL differential bus. The CAN connectors are actually a stacked pair of eight-pin RJ-45 female connectors with integral LED indicators. The stacked pair provides a perfect pass-through connection for the CAN cabling.

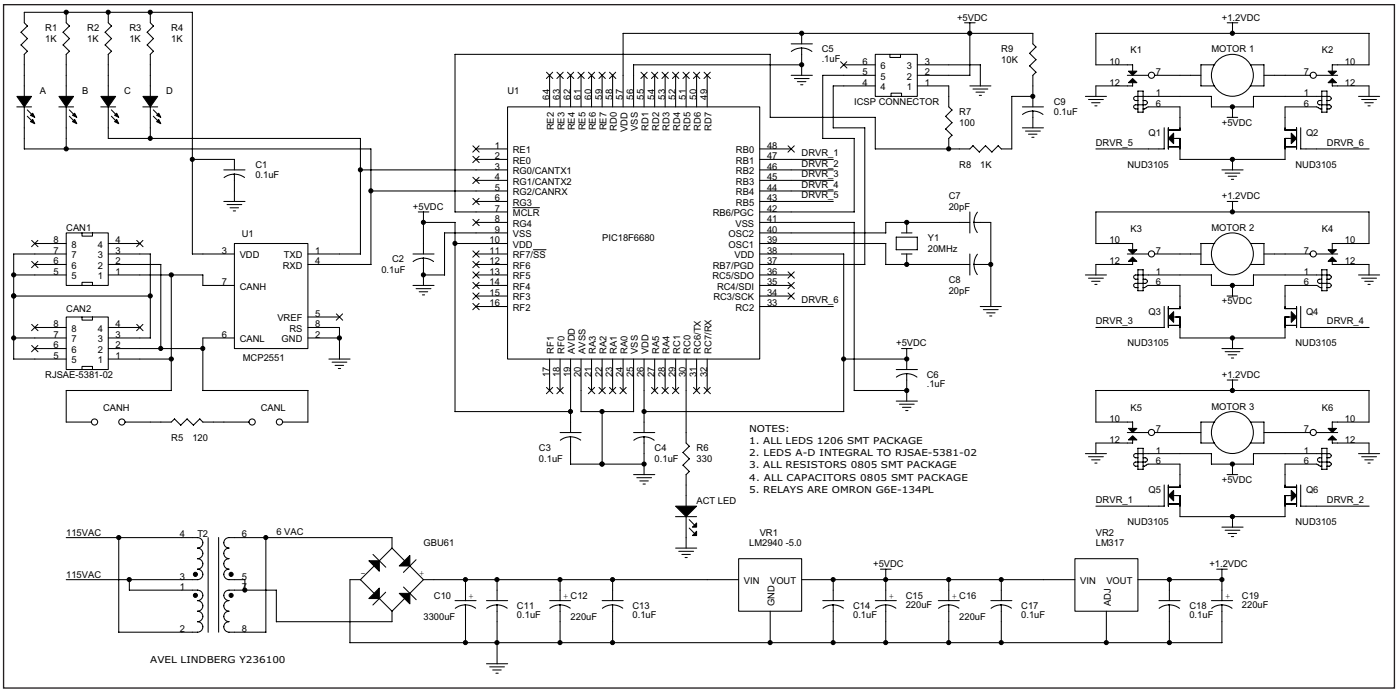
So, with this hardware the student interfaces with the Visual Basic application which communicates serially over USB to the PIC18F4680. Firmware within the PIC determines how to route the commands and data allowing the student to manipulate the local LED and motor on remote network nodes. With that, let's move on and analyze the motor node hardware.

A RECYCLED MOTOR NODE

The PIC18F6680 is definitely overkill in this

■ SCHEMATIC 1. The Lenovo NetBooks don't have nine-pin serial interfaces and I didn't want to have to power each node from a wall wart. So, I needed a reliable and robust data network with the ability to be powered from a USB connection. The CAN engine embedded within the PIC18F4680 fulfilled all of my network requirements and the CP2102 easily handled the USB interface duties.





■ SCHEMATIC 2. I recycled a project that included a PIC18F6680, some relay drivers, a CAN interface, and an on-board regulated power supply to drive the ROBOTIS 1.5 volt motors. After all of the trace chopping and relay additions, here's the configuration I ended up with.

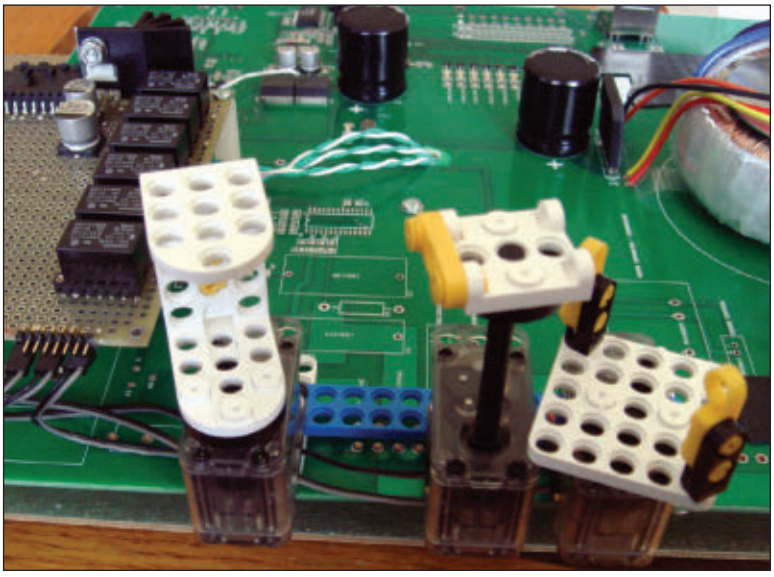
application. However, it came with a CAN interface, relay drivers, and a regulated multi-voltage power supply all on a single printed circuit board (PCB). All I had to do to create a motor node was carve out the parts of the PIC18F6680 board's circuitry I needed and add some motors and relays. The concept seen in **Schematic 2** is reality in **Photo 2**.

In the OLLO kits, the ROBOTIS motors are driven with a single AA battery. I couldn't find any specs on the motors. So, I accepted the 1.5 volt DC voltage as a design point. A simple 1.2 volt regulated power supply can be assembled using an LM317 adjustable voltage regulator with +5 VDC applied to its INPUT pin and its ADJ pin tied to ground. During testing, I discovered that running all three motors simultaneously for an extended period of time tended to heat the LM317 beyond a comfortable touching temperature. So, to be safe I placed a small finned heatsink on the regulator.

I didn't have any H-bridge ICs that could switch at the low voltage required by the ROBOTIS motors. However, I did have the components necessary to build up discrete low voltage H-bridges. I also had a tube of small SPDT relays. After sleeping on it, I decided that the relays would be easier to integrate into the design as I already had five volt relay drivers (NUD3105s) mounted on the recycled PCB. As it turned out, the relays were easily integrated and the relay logic I used to control the motors worked perfectly.

As you can see in Schematic 2, each motor is fed from a pair of relays. Each relay is controlled by an NUD3105 relay driver which is under the control of a PIC18F6680 I/O pin. When both relays are de-energized, the motor does not see a ground path and cannot rotate its shaft. The PIC18F6680 firmware does not allow for both relays to be energized at the same time.

However, if that were to happen, both of the motor inputs would be grounded and again the motor shaft would be forbidden to rotate. Thus, by energizing only one of the relays at any given time



■ PHOTO 2. The actual circuitry is built upon a recycled project board. You can see the bank of relays and the LM317 with heatsink mounted on a breadboard off to the left in this shot. The motors are 1.5 volt types that I pulled from a ROBOTIS OLLO kit. I added the OLLO blocks to make the motor direction easy to see and uniquely identify the motors to the students.

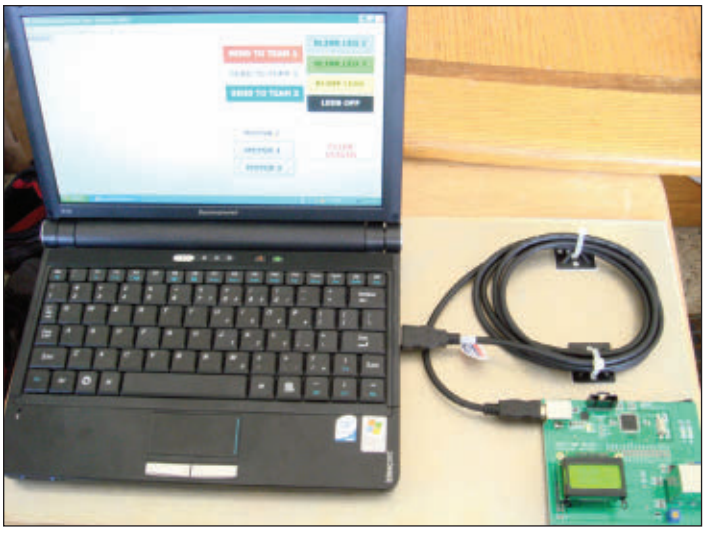
the motor shaft will rotate as the motor input connected to the de-energized relay would always see a positive voltage and the other motor input would have a ground path provided by the energized relay.

Thus, the mutual exclusive energizing of the relays forces the relay contacts to act as a mechanical H-bridge. The direction of the motor shaft rotation is dependent on which relay is energized.

THE COMPLETED SPACE DAY SCIENCE STATION

After assembling and testing with a network of one CAN node and the motor node, I assembled two more CAN nodes, programmed them, and attached them to the existing CAN network segment. I attached a Lenovo NetBook to one of the CAN nodes and successfully accessed the other pair of CAN node's LED 1 and LED 2 resources. I was also able to blink LEDs on the CAN node attached locally to the Lenovo NetBook via USB. Controlling all of the motors on the motor node via the network from the Lenovo NetBook was a success, as well.

With the help of some Velcro and a couple of wire ties, I mounted the Lenovo NetBook, a USB cable, and the CAN node on a 9" x 18" piece of 1/8 inch aluminum.



■ PHOTO 3. Here's what each student saw when they sat down at their science stations. I had 196 touchy-feely students pass through and use the trio of Lenovo NetBooks for 20 minutes per session. The NetBooks toughed the whole day out without a single malfunction or failure.

Five adhesive rubber feet on the underside of the a luminum plate put the finishing touches on the science station you see in **Photo 3**. Things are good and I'm off to Sarasota.

Space Day was fantastic and the science station performed beyond my expectations. Here's more good news. You can add Visual Basic interfacing and MarshallSoft's WSC4VB toolkit to your Design Cycle. **NV**

CONTACT THE AUTHOR

■ *Fred Eady can be contacted via email at fred@edtp.com*

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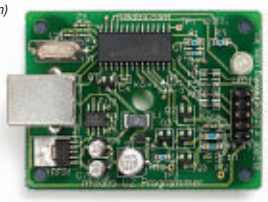

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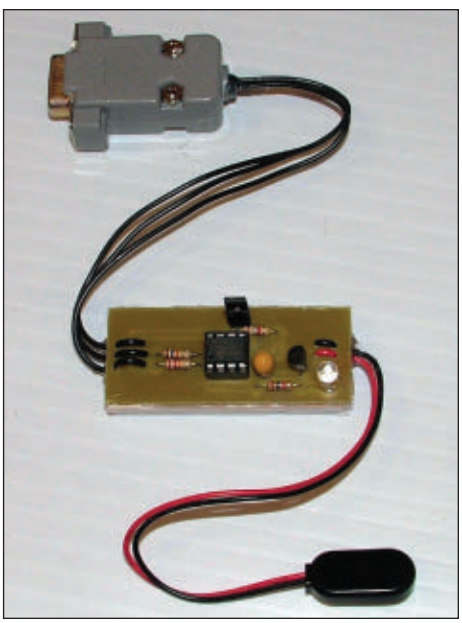
■ BY L. PAUL VERHAGE

GLOBAL POSITIONING SYSTEM SIMULATOR FOR MISSIONS TO NEAR SPACE

There are times I'd like to be with my near spacecraft to be sure it's operating properly. That can't happen though, unless I can hold my breath long enough to reach near space. While my near spacecraft is on the ground, I can plug a GPS into its flight computer and ensure it reads GPS sentences properly. That, however, isn't an adequate test; during an actual mission, the elapsed time and altitude keep changing. Therefore, what I need is a convenient GPS simulator that will let me test a flight program on the ground. In this article, I'll describe what I came up with.

A DESCRIPTION OF A NEAR SPACE FLIGHT

Basically, we fill the balloon, tie on a recovery system and payload, and let the darn thing go. The balloon rises at a nearly constant rate until it bursts and then begins falling rapidly to the ground. As the near space vehicle descends into denser atmosphere near the ground, its parachute becomes more effective at generating drag, slowing its descent speed until it lands.



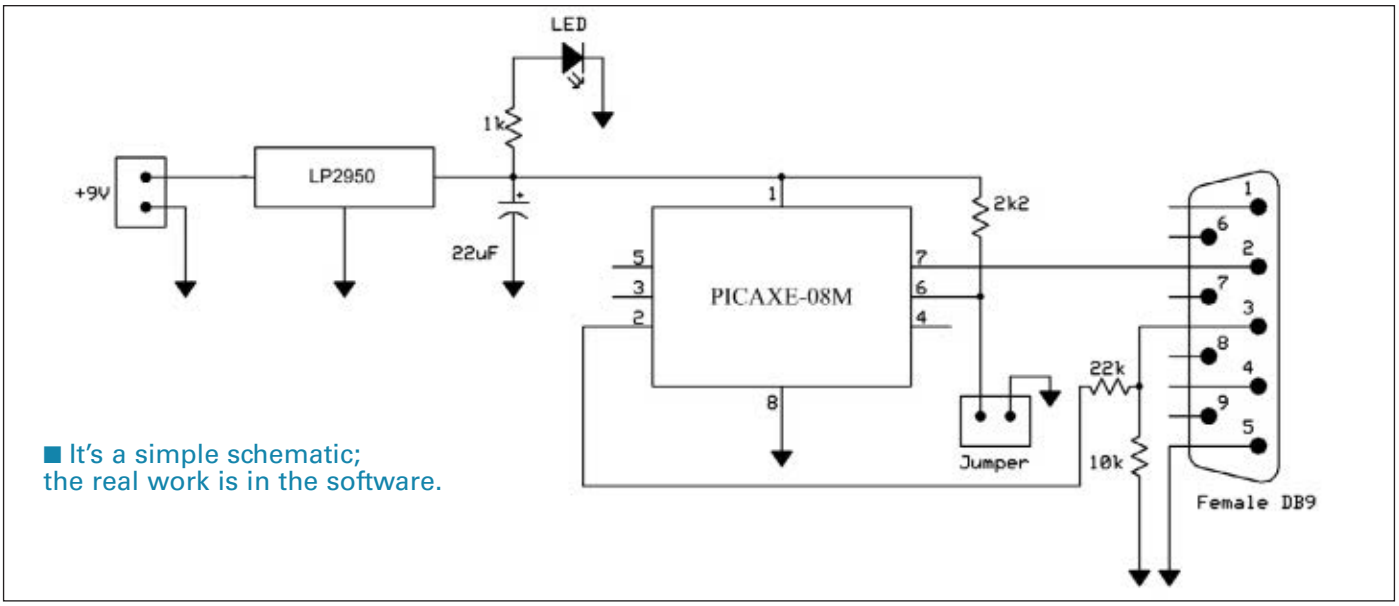
■ It's not a real GPS, but it plays one for flight computers.

The ascent rate of a balloon is influenced by the lift of the balloon, the weight it's lifting, and the drag on the balloon. Typical ascent rates are 800 to 1,500 feet per minute with 1,000 to 1,200 feet per minute being more usual. The descent speed at sea level is around 900 feet per minute and is influenced by the weight of the payload being landed, the diameter of the parachute, and the porosity of the fabric used in the parachute's canopy. As the air density decreases at higher altitude, the descent speed of the parachute increases by the inverse square root of the decrease in air density (for example, at 36,000 feet, the air density is 1/4 of the density at sea level and the descent speed is twice as fast).

This was a simple description of a near space flight. When we look carefully at a chart of the ascent of a near space mission, we observe that in most flights there's a small decrease (around 20%) in ascent rate at around 40,000 feet. My current understanding is that this "knee" in the ascent rate is caused by a change in the balloon's Reynolds Number. A closer observation of ascent rate charts shows a high frequency fluctuation in the ascent rate probably caused by GPS error and variations in wind speed (as the wind slows down, the balloon is pushed up because the air is forced up since air is a fluid and wants to avoid compressing if at all possible).

MAKING A FLIGHT COMPUTER THINK IT'S ON A MISSION

So, what I needed was a microcontroller programmed to create GPS-like sentences that behave like it's a GPS on a near space mission. I chose a PICAXE-08M for this purpose since I want to keep the price low and I thought the final program would



■ It's a simple schematic; the real work is in the software.

be small and simple (yeah, right).

To be realistic, the GPS simulator would need to start at some altitude other than zero feet, ascend at a near constant rate until the knee altitude is reached, and then continue ascending at a slightly slower rate until the peak altitude — apogee — is reached. The initial descend would have to be very fast, but gradually slow down as the landing was approached. The descent would have to conclude at some altitude above zero feet MSL. Throughout this simulated mission, the latitude, longitude, and time fields would have to change in a reasonable way. Because of memory limitations, the GPS Simulator doesn't reproduce the small, fast fluctuations in ascent speed. Nor does it produce all the sentences of a GPS receiver — it's limited to just the GGA sentence. The components for the GPS are few in number and all are common items:

- Nine volt battery snap
- LED
- Eight pin socket
- PICAXE-08M
- 10K resistor (1/4W)
- 22K resistor (1/4W)
- Female DB-9 connector (use one with solder cups)
- DB-9 housing
- Wire
- Two-pin header
- Shorting block
- 1K resistor (two of these)
- 22 µF capacitor
- LP2950 (TO-92 low dropout voltage regulator)
- Wire cut into three equal lengths (#24 AWG stranded works well)
- GPS Simulator printed circuit board (PCB)

Insert components with the lowest lying one first before moving on to the taller ones. I recommend adding components in the following order:

1. Resistors (10K, 22K, 1K, and 1K)
2. Nine volt battery snap *
3. Wires (three of equal length) *
4. IC socket (watch orientation)
5. Voltage regulator (polarized, watch orientation)
6. 22 µF capacitor (polarized, watch orientation)
7. Voltage regulator (polarized, watch orientation)
8. LED (polarized, watch orientation)
9. Two-pin header

* The PCB design includes strain relief for the DB-9 connector and the nine-volt battery snap. So, pass their wires through the strain relief holes (from the underside of the PCB) before soldering them to their pads.

The DB-9 is the programming port and GPS output port for the simulator. After soldering the three serial port wires to the PCB, add the DB-9 connector to the end of the wires this way.

— Strip 1/4 inch of insulation from the ends of the three wires.

— Solder the wires to the solder cups in the back of the DB-9 connector.

— Note that the cups are numbered so you can match the wires to the proper cups by noting the markings on the top silk diagram.

— Squirt a little hot glue over the solder cups and inside on half of a DB-9 housing.

— Set the DB-9 connector into the housing before the glue cools.

— Add additional hot glue over the wires.

— Fill most of the other half of the DB-9 housing with glue.

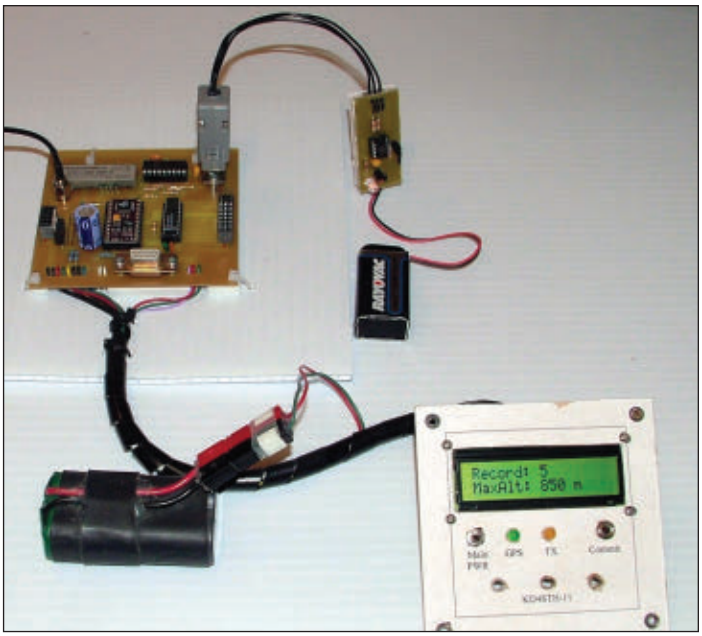
— Cover the DB-9 connector with the other half of the housing.

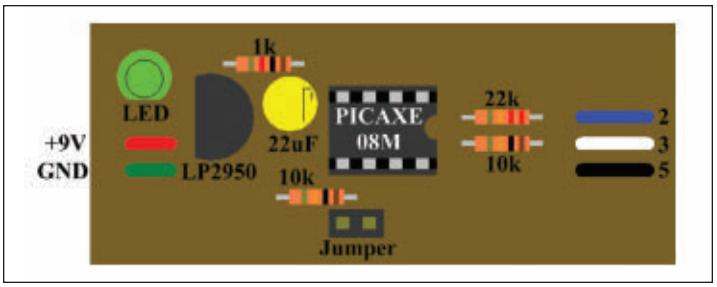
— Bolt the two halves together.

— Squirt hot glue into the opening in the back to seal off the DB-9 housing.

When it cools, you'll have a solid DB-9 serial connector with wires that won't break from normal usage. Before snapping the PICAXE-08M into the socket, check the circuit for errors with this procedure:

— Check the soldering for shorts.





■ Parts placement for the GPS Simulator.

■ Here's an example of a GPS Simulator test. The flight computer was programmed to blank out the LCD display above 10,000 feet and to display the highest obtained altitude on descent. The flight computer's program worked exactly as I planned and I didn't even have to send it up on a balloon!

— Measure the continuity between the two connectors in the battery snap (there shouldn't be any).

— Snap in a nine-volt battery and verify there's +5V on pin 1 and ground on pin 8.

— Verify there's +5V on pin 6.

— Add the shorting block to the two-pin header and verify the voltage on pin 6 is now 0V.

— Remove the nine-volt battery and snap the PICAXE into its socket.

— Snap in the nine-volt battery and connect the DB-9 connector to your PC's serial port.

— Start up the PICAXE programming editor and download the program included in the website package.

DEBUG

You should get a terminal window with a single response showing that all variables are equal to zero.

After verifying the GPS Simulator is working properly, remove the battery and get a thin sheet of plastic or Foamcore. Cut it to the same size as the PCB and hot glue it to the bottom of it. The sheet protects the traces and pads on the underside of the PCB from accidentally shorting out. Now you're ready to download the simulator program from the *Nuts & Volts* website at **www.nutsvolts.com**. The sample program produces a GGA sentence every second and the sentences look valid as long as your flight code doesn't verify the checksum at the end of each sentence. Here's an example of what the GPS Simulator output looks like.

```
$GPGGA,120000.00,3812.101,N,98
010.101,W,1,07,1.1,320.0,M,18.3,M,,
*78
$GPGGA,120001.00,3812.102,N,98
010.102,W,1,07,1.1,340.0,M,18.3,M,,
*78
$GPGGA,120002.00,3812.103,N,98
010.103,W,1,07,1.1,360.0,M,18.3,M,,
*78
```

The GGA sentences above have the following fields: GPGGA, Time (UTC), Latitude (degrees, minutes, and decimal minutes), N(orth), Longitude (degrees, minutes, and decimal minutes), W(est), 1 (for GPS lock), Number of satellites, 1.1 (amount of dilution of horizontal precision), Altitude (meters), Altitude of the Geoid (meters), and a checksum.

Notice the time, latitude, longitude, and altitude fields change smoothly with every sentence just like they do during a near space flight.

SIMULATOR PROGRAM SETTINGS

To adapt the GPS simulator to your particular situation, there are five settings at the beginning of the program to tweak. The variables and their definitions are:

LaunchAltitude: The altitude of the launch site in meters.

InitAscentRate: The ascent rate of the balloon in meters/per second.

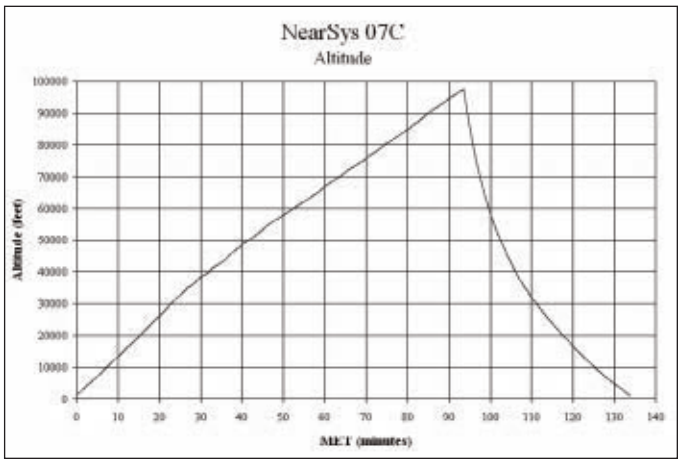
KneeAltitude: The altitude that the ascent rate knee occurs.

BurstAltitude: The balloon's burst altitude in meters.

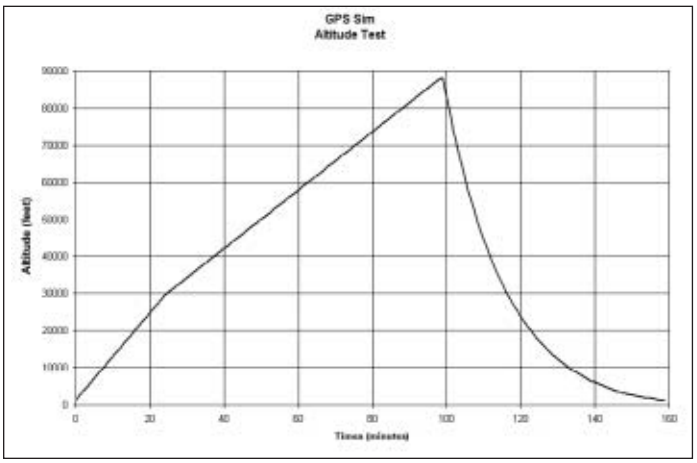
RecoveryAltitude: The altitude or recovery site in meters.

In addition, you can edit the SERTXD command near the end of the program to move the latitude and longitude of the launch site.

To test the code you've written for a flight computer, just plug the GPS Simulator into the GPS port of the flight computer. As soon as the nine-volt battery is snapped in, the simulator begins generating GGA sentences like the flight computer's GPS was really going into near space. By changing the five settings mentioned previously, you can simulate a variety of near space mission profiles — even ones where the balloon bursts sooner than expected or climbs higher than desired. With a slight modification, you can even simulate a balloon becoming neutrally buoyant. Take a look at the charts included here for a



■ The altitude chart from a real near space mission. Notice the knee in the ascent.



■ Here's a chart of altitudes recorded by a flight computer during a simulated mission. Notice the knee is there.

comparison of flights recorded by a flight computer during a real near space mission and one recorded during a simulated mission.

IS THAT ALL?

I want to tighten up the code I'm using for the GPS simulator because in its current state, there's too little room left for additional features. For example, I included the jumper in this design as a way of simulating a GPS getting or losing a position lock. When the jumper is not in place, the simulator's code would produce sentences with the time field blanked out and the altitude field left unchanging. When the jumper is in place, it would go back to displaying properly updated time and altitude fields. So, before outputting each sentence, the simulator code would inspect pin 6 to see if the shorting block was in place. However, before I can make that happen, I'll have to work on the code some more.

At some point, I'll have to design an advanced version of the GPS Simulator that produces more

THE REYNOLDS NUMBER

The Reynolds Number (Re) is named after its inventor, Osborne Reynolds who developed the concept in 1883. Originally, it was used to help analyze fluid and heat flow problems. By looking at the Reynolds Number for a balloon, we can determine if the air is flowing around the balloon smoothly or turbulently as it ascends. We can also use the Reynolds Number to determine if a scale model of the balloon will perform like the life size version. The Reynolds Number is based on factors like the balloon's diameter, the air's density, and the ascent speed of the balloon. You can read more about Reynolds Number at Wikipedia (**http://en.wikipedia.org/wiki/Reynolds_number**).

The equation for Reynolds Number can be written as follows (we'll treat the balloon as being spherical):

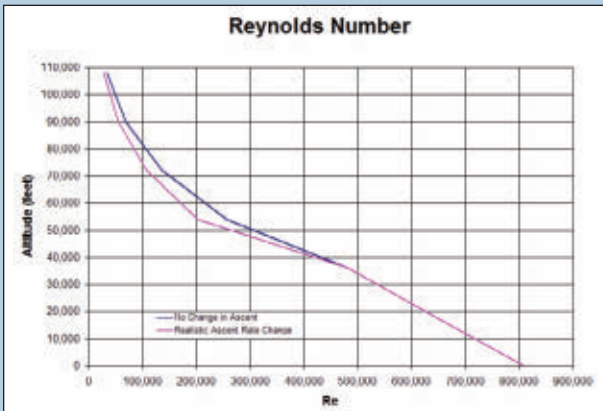
Re = pVD/u

where
p = density of the air
V = ascent rate of the balloon
D = balloon's diameter
u = dynamic viscosity of the air

Now, rather than try to calculate the Re during a balloon flight, I went to NASA's website (**www.grc.nasa.gov/WWW/BGH/viscosity.html**) and entered the balloon's diameter, ascent speed, and altitude into their applet. Using this information, I created a chart of a balloon's Re at 18,000 foot intervals (since every 18,000 feet the air pressure drops by a factor of 50%, making it easier to calculate the balloon's diameter). I did this the first time assuming that the ascent rate doesn't change above the knee altitude and then a second time with a more realistic decrease in ascent speed of 20% above 40,000 feet. Take a look at the resulting chart. According to the Engineering Toolbox (**www.engineeringtoolbox.com/reynolds-number-d_237.html**), the Reynolds Number can determine if the air flow over the balloon is laminar, turbulent, or in between.

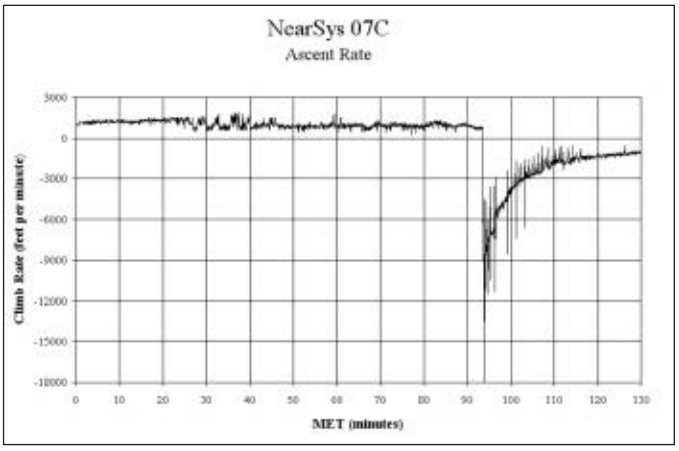
Drag on the balloon is lowest when the air flow is laminar and air flow over the balloon is laminar only when the Reynolds Number is below 2,300. In the included chart, we see that the Reynolds Number never gets that low, although it is getting lower during the ascent. For the entire ascent, the air flow is turbulent around the balloon, although perhaps generating less drag.

However, if that were the case, I would expect the balloon's ascent rate increase throughout the ascent. Since the ascent rate remains constant except for the change at the knee, there's got to be more than the Reynolds Number affecting the balloon.

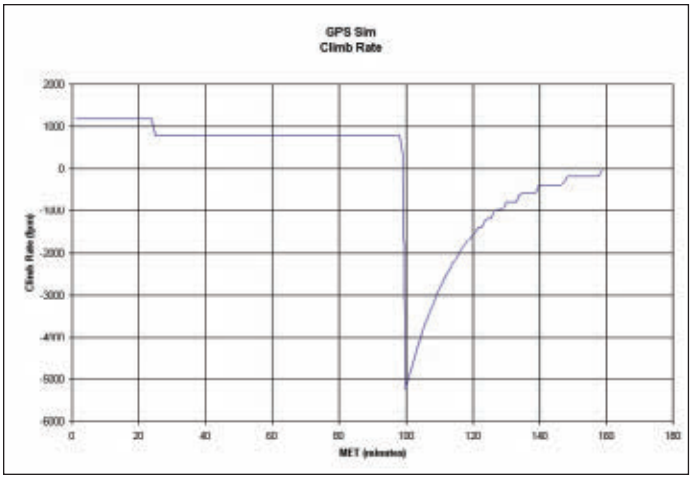


■ Well, I'll be darned if I can find anything that makes sense here. I wasn't expecting the Reynolds Number to decrease above 40,000 feet nor for it to get even lower in the more realistic calculation.

■ This is a chart of the variation in ascent rate during a real near space mission.



■ The simulation ascent rate looks close enough to the real one for most tests you'll need to perform. What's missing from this chart are the tiny high frequency variations in the ascent rate that really don't matter to a flight computer anyway.



sentences. I primarily need the GGA and RMC sentences, but other people might like to see all of them. It would be a bit of overkill I/O wise, but the advanced version will probably need a PICAXE-18X or larger.

Enjoy using the GPS Simulator to test your flight computer's code. You'll find it's useful if your flight computer is programmed to react to milestone altitudes (like releasing dropsondes at 50,000 feet and cutting away the balloon at 95,000 feet) or milestone events (like operating a cutdown and shutting down experiments at balloon burst). If there's an interest, I'll produce a solder kit of the GPS Simulator. (I imagine it will cost around $20.)

Onwards and Upwards,
Your near space guide **NV**

READER FEEDBACK

continued from page 11

FLASH(ING) BACK

WOW!

I had to do a double take on the 360/91 front panel (Personal Robotics, June '09 *Nuts & Volts*).That was one of my favorite front panels. At SLAC (Stanford University Linear Accelerator), I was maintaining a couple of strings of disk drives (dual port with four-way switched controllers built by ISS for ITEL) that were attached to the selector channel. Also in the room were a couple 370/168s with block mux channels.

Getting these drives to co-exist with these three mainframe channels took some standalone time. That's where I got to use the Model 91's front panel. I could show every bit in the machine ... very cool. I think it had six megabytes of core memory that was modular (on wheels). They kept a spare megabyte in the back room that could be swapped out and then the bad bit replaced!

I discovered from the IBM field engineer that the lamp test button would drop AC breakers if held down for too long. That was the day — when I got to push the lamp test button on a 360/91!!!

Jeff

P.S. NASA had a 360/67 that was used on the wind tunnel — another interesting (not as graphic) front panel.

SPEAKING HIS LANGUAGE

Thank you for the April '09 Fred Eady article "Older Language, Newer Interface." I really found it informative.

I downloaded the Tera Term terminal program and found it very useful. Especially the part where you can save log files automatically which can be used by other software later.

To me, the VCP and terminal program looks easier to do than the FTD2XX.DLL and classical or API and customer application software.

Paul Treciokas

continued on page 93

BUDGET ROBOTICS

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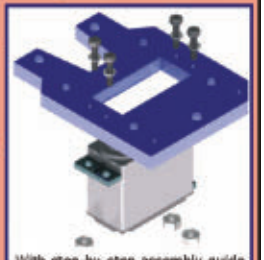

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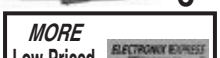

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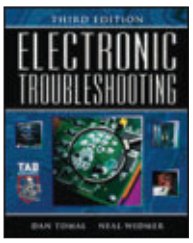
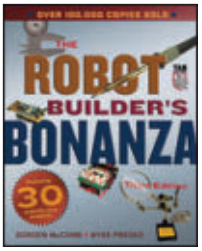
"EDITOR'S PICKS"



Electronic Troubleshooting

Developing electronic troubleshooting skills can take years — or a few months with the proper resources at your fingertips. *Electronic Troubleshooting* is one of those resources. Not only does it provide a modest degree of handholding for readers new to the myriad test equipment available today, but the authors offer heuristics developed from their years of practical experience in the art of troubleshooting. This is a good book for beginners.

$49.95*



Robot Builder's Bonanza

Virtually all electronics projects involve both components and some sort of mechanical assembly. Often, it's too easy to focus on the electronics and forget about the mechanical systems. *Robot Builder's Bonanza*, while focused on robotics, provides a wealth of information for every hobbyist who wants to integrate hardware and software. If you work with motors, sensors, and hardware platforms, you owe it to yourself to add this reference source to your bookshelf.

$59.95*

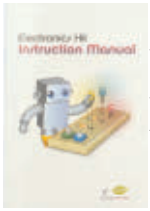
Editor Bryan Bergeron's recommended reads.
Find these and many more great titles in the *NUTS & VOLTS* Webstore!

ELECTRONIC NEWBIE

DIY Design Electronics Kit

This great kit contains everything you need to learn the basics of electronic circuit design. It contains all of the most common electronics components as well as a prototyping breadboard for you to get started right away.

The kit has over 130 parts!



No soldering is required and the included 32 page illustrated manual guides you through each of the projects. After you build all of the projects, you can use the parts for your own designs.

NEW!

For a complete product detail, please visit: http://store.nutsvolts.com **$49.95***

ELECTRONICS

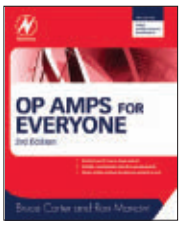
Programming 8-Bit PIC Microcontrollers in C
by Martin P. Bates

Step-by-step, practical instructions on how to program PICs in C, with no prior experience necessary!

PIC Microcontrollers are present in almost every new electronic application that is released from garage door openers to the iPhone. With the proliferation of this product more and more engineers and engineers-to-be (students) need to understand how to design, develop, and build with them. Martin Bates, best-selling author, has provided a step-by-step guide to programming these microcontrollers (MCUs) with the C programming language.

$39.95

Op Amps for Everyone, Third Edition
by Bruce Carter and Ron Mancini

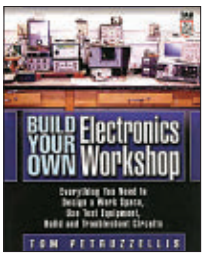


OP AMPS FOR EVERYONE provides the theoretical tools and practical know-how to get the most from these versatile devices - this new edition substantially updates coverage for low-speed and high-speed applications, and provides step by step walkthroughs for design and selection of op-amps and circuits.

$79.95*

Build Your Own Electronics Workshop
by Thomas Petruzzellis

YOUR DREAM ELECTRONICS LAB IS WAITING INSIDE!



This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems — popular electronics author Tom Petruzzellis' *Build Your Own Electronics Workshop* has it all! And the best part is, this book will save you money, big time!

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Audel Basic Electronics
by Paul Rosenberg

NEW!

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Over the past hundred years, electronic technology - especially digital - has transformed our world. If you're in the electrical trade or studying to be, there's a lot to learn and even more to keep up with. You need a directory of the basics, with chapter summaries, common symbols and abbreviations, a glossary, and more - one that's both study a guide and ready reference.

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Making PIC Microcontroller Instruments and Controllers
by Harprit Sandhu

Harness the power of the PIC microcontroller unit with practical, common-sense instruction from an engineering expert. Through eight real-world projects, clear illustrations, and detailed schematics, *Making PIC Microcontroller Instruments and Controllers* shows you step-by-step how to design and build versatile PIC-based devices. Configure all necessary hardware and software, read input voltages, work with control pulses, interface with peripherals, and debug your results.

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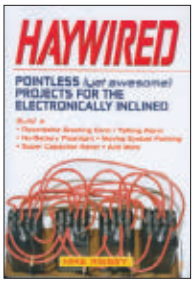
Haywired
by Mike Rigsby

Construct a no-battery electric car toy that uses a super capacitor, or a flashlight that can be charged in minutes, then shines for 24 hours. Written for budding electronics hobbyists, author Mike Rigsby offers helpful hints on soldering, wire wrapping, and multimeter use. Each project is described in step-by-step detail with photographs and circuit diagrams. Includes websites listing, suppliers and part numbers.



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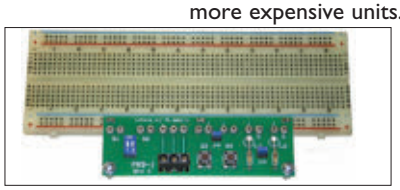

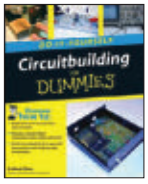

Combo includes PCB & Components, 830 point SBB, and *Do-it-Yourself Circuitbuilding For Dummies*.

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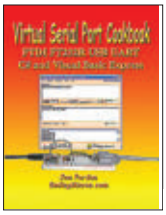


Virtual Serial Port Cookbook

by Joe Pardue
As talked about in the *Nuts & Volts* June issue,
"Long Live The Serial Port"

Book **$44.95**
Kit **$69.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

The Virtual Serial Port Parts Kit and CD

(also *available, above right*)

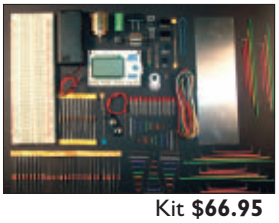
Reg. Price $ 114.90 **Subscriber Price $109.95 Plus S/H**

Book **$44.95**

From the Smiley Workshop

C Programming for Microcontrollers

by Joe Pardue



Kit **$66.95**

Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board and the FREE WinAVR C compiler to make a veryinexpensive system for using C to develop microcontroller projects.

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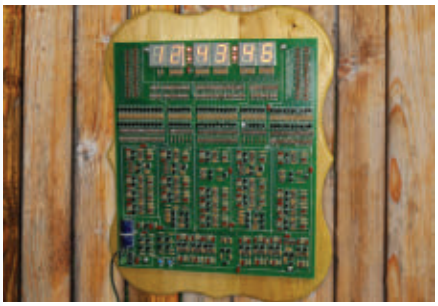

If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components! For more info, see page 42, this issue.
Subscriber's Price **$214.95**
Non-Subscriber's Price **$225.95**
PCBs can be bought separately.

Arch-Ball Clock PCB & MCU

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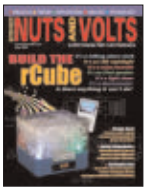
rCube Talking Alarm Clock Kit

As seen on the May 2009 cover



Available in blue, black, red, and green. All components are pre-cut & pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.
Subscriber's Price **$49.95**
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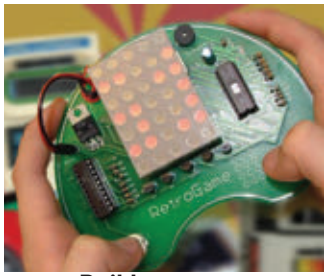
PCBs can be bought separately.

Retro Game Kit



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October 2006

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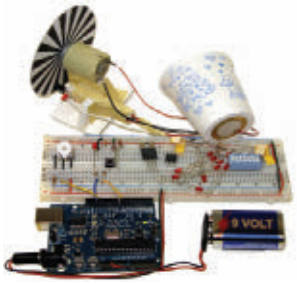
Arduino Project Kit From the Smiley Workshop



Blink LEDs (Cylon Eyes). Read a button and 8-bit switch. Sense Voltage, Light, and Temperature. Make music on a piezo element. Sense edges and gray levels. Optically isolate voltages. Fade LED with PWM. Control motor speed and more.
Price $79.95 Plus S/H

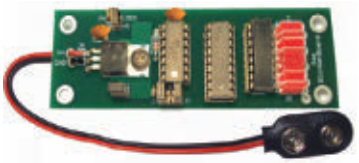
Big Ear Big Kit

As seen on the December 2009 cover

Ever wish you could build an "audio telescope" that would let you hear things that were faint or far away? Then this kit is for you! Just follow along with the article and you will see how to put together your own "BIG EAR!"
Subscriber's Price **$98.95**
Non-Subscriber's Price **$111.95**
Kit Includes an article reprint.

Das Blinkenboard Kit

This kit includes a preprogrammed ATtiny84 microcontroller that sports eight software PWM channels to control motor speed and light brightness. Jumper selectable patterns can be used to operate motors, solenoid valves, relays. Expand your board with GNU/GPL software updates to be featured in upcoming *NV* articles.



Subscriber's Price **$32.45**
Non-Subscriber's Price **$35.95**
PCBs can be bought separately.

DC-to-DC Converter Kit

As seen on the March 2009 cover

"Roll Your Own" Transformer that is!
With this project, you design and wind a transformer and use it to get +12V and -12V from a 9V battery from the DC-to-DC converter.
Subscriber's Price **$37.49**
Non-Subscriber's Price **$39.95**
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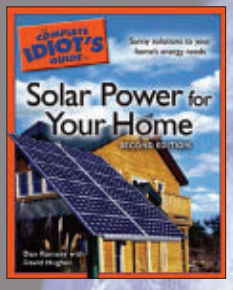
ALTERNATIVE ENERGY SECTION

The Complete Idiot's Guide to Solar Power for Your Home
by Dan Ramsey / David Hughes
Publish Date: May 2007



The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems. **$19.95**

Solar Hydrogen Power Generation Set

The Solar Hydrogen Generation Set includes a solar cell, a PEM reversible fuel cell, as well as oxygen and hydrogen gas containers. The set only needs pure water to create hydrogen and produce electricity. Perfect for science labs, classroom use, or demonstration purposes.
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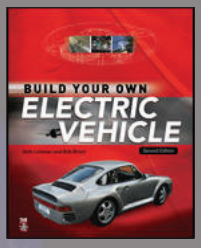
Build Your Own Electric Vehicle
by Seth Leitman, Bob Brant
Publish Date: October 10, 2008
Go Green-Go Electric! Faster, Cheaper, More Reliable While Saving Energy and the Environment!

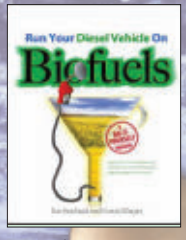


This comprehensive how-to goes through the process of transforming an internal combustion engine vehicle to electric or even building an EV from scratch for as much or even cheaper than purchasing a traditional car. The book describes each component in detail---motor, battery, controller, charger, and chassis---and provides step-by-step instructions on how to put them all together. **$29.95**

50 Green Projects for the Evil Genius
by
Jamil Shariff

Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life! **$24.95**

Run Your Diesel Vehicle on Biofuels
A Do-It-Yourself Manual
by Jon Starbuck, Gavin D J Harper



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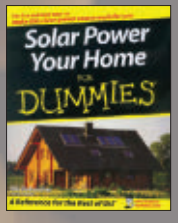

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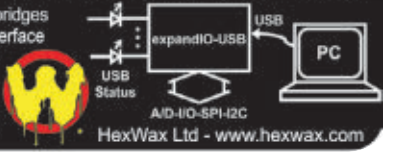

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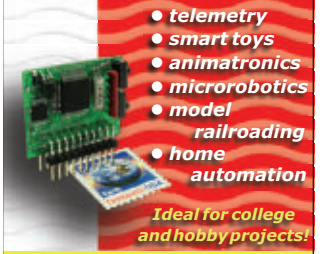

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READER FEEDBACK

continued from page 87

Thanks for reading, Paul!

Yep, the API stuff is really intended for commercial "product unique" applications. For guys like us, the basic bare bones, get it done stuff works just fine.

You can also use the Tera Term Pro scripting language to program the way the terminal acts and responds. The scripting commands allow you to do things at the terminal level that you would normally have to program in at the PIC or PC level.

For instance, you can write a simple TTP script that sends a character to the PIC every second. Or, you could write a script that waits for a particular character from the PIC to kick off a canned response.

Fred Eady

(DE)MISTY OVER USB

Well, "Demystifying USB to Serial" (p.60 *Nuts & Volts* 3/09) left me still a little mystified ...

1. Wouldn't it be simpler, at least for techie types, to use a readily-available PC-based USB to RS-232 converter? I can see for a supposedly consumer application where you might feel obliged to do this.

2. Even then, I would *much* prefer the CP2102/3, its circuitry, and anything else already built into a little plastic box I could just mount on my project; serial into one side, USB out the other. I mean, as opposed to having fun with surface mount. Am I correct in assuming there is no such thing available? And if so, how come?

Both of these things are still mystifying me. I don't watch that carefully, but I definitely feel somebody should make the #2 gadget before me, at any rate, stop using the #1 approach. As far as I can tell, industrial customers, at any rate, couldn't care less.

J.G. Owen

Thanks for reading, Mr. Owen.

The answer to Question 1 depends. If all you really want to do is replace a PC serial port, the USB dongle is the way to go. I have lots of them in the shop and use them quite often.

On the other hand, if you want USB conversion built into your project/product, you embed it. Or, if you want your project/product to appear to the customer as a USB plug-and-play device, you again embed the USB interface.

*The answer to Question 2 is yes. You can buy the CP210X dev kits from Si Labs which are USB in on one side and RS-232 out the other. The dev kits are intended for experimentation and contain a ton of jumpers. You can also get plug-in modules from DLP Designs (**www.dlpdesign.com**). These are intended for production or experimental use.*

The idea behind the article was to show folks that they don't have to use an off-the-shelf USB solution and that it is very easy to roll your own embedded USB interface hardware and firmware. The article also shows the reader how inherent USB methodology can be used to eliminate having to include power supply circuitry and a MAX232-based RS-232 IC into a PIC design that has to interface to a USB host device.

Hopefully, that clears some of the smoke.

Fred Eady

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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Wind Speed Controller

I need a circuit for several applications that need to be switched on/off (open/closed) by relay, depending on wind speed.

The circuit needs to be able to set a minimum wind speed to activate and a maximum wind speed to deactivate. Also, it needs variable activate and deactivate timers (about 30 seconds to five minutes) so that wind gusts will not activate/deactivate the circuit too rapidly.

There are several stand-alone wind speed devices on the market, as well as included in complete weather stations. They all seem to be wireless in nature and talk to some type of receiver monitor or computer. A stand-alone "wired" wind speed device to controller circuit would be preferred.

#7091 Vonn Hockenberger
Livermore, CA

Inventory Tracking

We have been trying to find a better way to keep track of thousands of inventory items we have on campus. We would like to do this the cheapest and most effective way. Our budget right now is not that large. We have looked at a few applications from iTunes App store, but most of them are web based – "Info already on the web." I was wondering if RFID chips could do this sort of thing? We want to put the serial number, item name, and model number into either a barcode or chip that can be stuck to the item. Is the RFID system able to do this or very inexpensive barcode software? The RFID I am talking about uses those little chips like you find inside a passport.

#7092 Harlan
Springfield, MO

Simple Low Frequency Transmitter

How would I build a low frequency (say 512 Hz), battery operated sine wave transmitter that was small enough to fit inside 1" PVC pipe? I'm not sure if a resistor, capacitor, or crystal is the best; how do you wind a coil antenna to match the frequency?

#7093 Gordon Eden
Naperville, IL

Microcontroller Circuit

I want to build a project using a BASIC Stamp 2p40 to allow me to reset pin setters at the bowling alley I work at from the front desk. I need a way to interface between the BASIC Stamp and the pin setters. The reset button is a 24 VAC circuit and I will be connecting in parallel with the reset switch. I was thinking about using something like an opto-isolator but I want to be able to reset multiple lanes at the same time and am concerned because the Stamp can only sink 60 ma/eight pins, and from what I have seen in opto-isolators,

they take 10 ma on the input. This would mean if I reset all lanes at the same time, I would need to sink 80 ma/eight pins. Am I going about this the wrong way or is there a better way to interface between the Stamp and the pin setters?

#7094 **Chad Geist**
Fargo, ND

Curb Sensor

I would like a circuit to build an electronic automobile curb sensor.

#7095 **Lynn White**
via email

>>> ANSWERS

[#3093 - March 2009] Matching Transistor Gains

I am looking for a practical vs. exotic bench setup to determine the gain of some power TO-3 transistors. I'm working with an old piece of equipment that requires matched transistor sets. It was going to be replaced in the near future, but "near" is beginning to look like "someday." So, for the indefinite future, we need to keep the existing units alive and the dead ones restored.

#1 A web search for "transistor gain test" returned testers from simple to complex that should work for your needs. Also **jameco.com** has some inexpensive DMMs that have gain tests built in. A TO-3 test socket would also be a good item to have.

Bob Lindstrom
Broomfield, CO

#2 The magazine *ELEKTOR*, vol. 35, February 2009 #386, page 24 (**www.elektor.com**) shows the design of a very elegant and useful curve tracer. It will test and compare NPN and PNP transistors, N and P JFETs and MOSFETs. Control and data via USB to a PC. Software available — free — from *ELEKTOR*. They also can, for a reasonable fee, supply the PC boards. You also can get the whole thing as a kit or completely built.

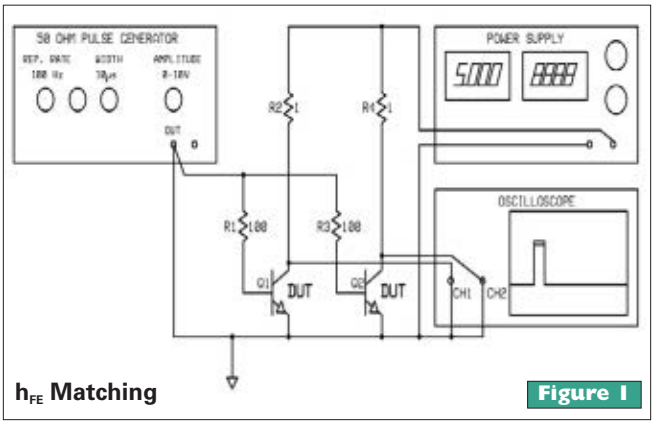
www.elektor.com/magazines/2009/february/transistor-curve-tracer.810360.lynkx

Since David expects to test transistors for quite a while, this is a very good solution. Alternatively, he can try to find an old Tektronix curve tracer, but if it fails he may not find any spare parts.

If David cannot find a copy of the aforesaid magazine, he can email me and I'll send him a copy.

Paul J. Weijers
paul.weijers@videotron.ca

#3 Most DMMs have an h_{FE} function, but measure at a few µA base current. If you need to match at higher currents, see **Figure 1**. Keep heat input — especially from your fingers — to a minimum to avoid measuring at different conditions and leading to incorrect results. Temperature increases h_{FE} dramatically. Drafts and sunlight are other problematic sources of heat. The suggested setup will have an 0.1% duty cycle and therefore a rather small heat input, even at momentarily high power. R2, R4, and the power supply voltage can be adjusted to fit your needs. You may be able to use just one pulse with a storage scope, but the pulse(s) may need to be lengthened for some slow devices. The 50 ohm pulse generator can deliver as much as 187 mA to the bases of the transistors. Most function generators with 50 ohm output should work also. VBE can be matched by connecting to the bases. If you want to read more about this and related subjects, the best source in my view, is *Semiconductor Device Measurements* by John Mulvey in the Tektronix Measurement Concepts Series (free as a PDF on the Internet).



h_{FE} Matching — Figure 1

Walter Heissenberger
Hancock, NH

[#3094 - March 2009] ESD Protection

I have designed and built a USB dumb data terminal for time and attendance tracking. Now that the device is in production, static discharge resets the MCU. It's a very simple design using only an LCD, PIC chip, membrane switch (with grounding layer), a plastic enclosure, and a USB cable to connect to the computer. I have a grounding layer on the PCB and the cable's shield and the membrane grounding layer are connected to it. Routing the membrane grounding layer to the cable shield bypassing the PCB ground improves ESD performance, but not completely.

#1 Reset issues due to ESD can be solved by the following methods:

1) Add a 1K to 2K ohms resistor in series with the /MCLR pin on the PIC. In PIC microcontrollers, the /MCLR pin doubles as a programming voltage pin when used in In-Circuit Serial Program (ICSP) mode. Typical ESD voltage can exceed the ICSP program voltage and reset the part as part of the beginning of the program cycle.

2) If #1 does not solve the issue, add a 0.1 µF, 50V ceramic capacitor across the Vdd and Vss pins. This will act like a decoupling capacitor and take the ESD energy away from the microcontroller power pins. If the micro you are using has more than one pair of Vdd-Vss pins, a capacitor is needed on every Vdd and Vss pair of pins.

3) If #1 and #2 do not solve the issue, add a 10 µF 16V electrolytic capacitor across the power lines (Vdd-Vss) to smooth out the ripples caused by ESD voltage.

Raj Yedamale
Chandler, AZ

#2 First of all, make sure that the RESET input to your PIC is not floating. It should have a pullup/pulldown resistor to keep it in the un-RESET

state. Something like a 4.7K will do. Next, make sure you have proper decoupling on your active devices. A 0.1 µF capacitor — as close to the power and ground pins as humanly possible — is required on each device. Be sure you have a reservoir capacitor — something like a 10 µF-1,000 µF electrolytic capacitor — between your power and ground where the power comes into the board.

Hank Jones
El Lago, TX

[#3095 - March 2009]
Voltage Regulators for Bicycle Lights

I have an electric bicycle that runs on 36 VDC and would like to make a circuit that would power the lights and radio on the bike. There are four items all powered by various quantities of AAA batteries. There is 1@6V, 1@4.5V, and 2@3V.

We don't know the current load of the lamps. However, we can make an educated guess based on the use of AAA cells. According to Digi-Key's website, an En92 AAA alkaline cell has a capacity of 1,250 mAHr. Most cells work well at a C/10 rate; 125 mA for 10 hours. We assume that a higher practical absolute limit is C/1; a discharge rate of 1.25A for an hour. That is, we assume that your 6V lamp draws no more than 1.25A. We make the same assumption for the 3V lamps: no more than 1.25A. Further, we assume that the 3V lamps are identical. We propose to place the two 3V lamps in series so they may be driven from the same 6V supply powering the 6V lamp. We estimate that a small 4.5V radio draws no more than 50 mA. It will be powered by a 4.3V zener regulator drawing 50 mA from the 6V supply. We need a 36V to 6V switching regulator capable of the total current:

1 @6V	1.25A
2@3V in series	1.25A
1@4.5	0.10A
total =	2.60A

To design the switching regulator, go to **www.national.com/analog/webench** and select "Power" using their online design tool.

Input the following: Vin MIn=24, Vin max=45 Vout=6, Iout=2.60, Ambient (C)=30. Select "Start Design." Next, select "Start Your Design LM5576." At some point, you will need to create a user login if you don't already have an account. The result is a bill of materials (BOM) and a schematic diagram. See **Table 1** and **Figure 2** for the BOM and schematic. BOM cost is about $36.

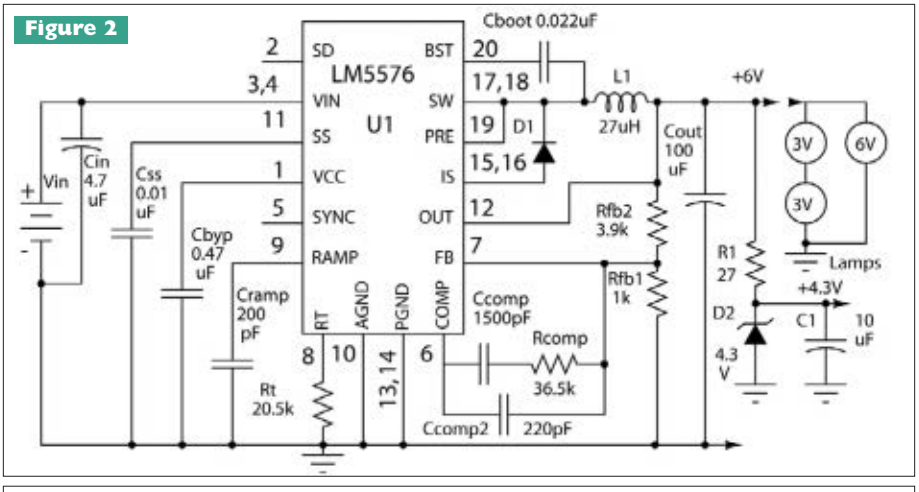
The design produced by Analog Workbench needs to have the parts for the zener regulator added: D2, R1, C1. This has been added to the right side of the schematic. We also show the 6V and 3V lamp loads. The BOM lists a part number for a circuit board with the LM5576 SMT soldered in place. This circuit board makes no provisions for D2, R1, C1. The board is an easy way of dealing with the SMT parts.

What could go wrong? According to **http://nordicgroup.us/s78/12volt6volt.html**, the lowest wattage 6V bicycle H3 head lamp is 25 watts, over 4A current. However, that can't be driven by AAA cells. Determine the actual current draw of your lamps, and decide if this design is applicable. For higher current lamps, re-do the design with the appropriate current. If the two 3V loads are not identical and cannot be placed in series, you need two supplies: 6V and 3V. Run Analog Workbench for both at the required current. When testing the supply, check the 6V output. Then add D2, R1, C1, and check that output for 4.3V. Connect your 4.5V load, the radio, and check the 4.3V again. If the voltage is loaded down severely by the radio, decrease R1 to supply more current so that the zener may regulate.

If you customize the design with Analog Workbench, try to force it — if necessary — to use the LM5576, a 75 volt tolerant part, over any of the 40V parts. We have reason to believe that starting and stopping the motor will generate transients on the power line, which could damage the more common 40 volt tolerant regulators.

Dennis Crunkilton
Abilene, TX

Figure 2



3	Nippon Chemi-Con	APXE100ARA680ME61G	68 µF, ESR = 0.028 ohms	Cout
4	TDK	C5750X7R2A475M	4.7 µF, ESR =0.0015 ohms	Cin
5	Yageo America	CC0805KRX7R9BB222	0.0022 µF	Ccomp
6	Yageo America	CC0805KRX7R9BB331	0.0003 µF	Cramp
7	Vishay-Dale	CRCW04021k00FKED	1,000 ohms	Rfb1
8	Vishay-Dale	CRCW040220k5FKED	20,500 ohms	Rt
9	Vishay-Dale	CRCW040224k9FKED	24,900 ohms	Rcomp
10	Vishay-Dale	CRCW04023k90JNED	3,900 ohms	Rfb2
11	Panasonic	ECJ-2VB1H223K	0.022 µF	Cboot
12	Panasonic	ECJ-2VC1H820J	82 pF	Ccomp2
13	Taiyo Yuden	EMK212B7474KD-T	0.47 µF	Cbyp
14	MuRata	GRM216R71H103KA01D	0.01 µF	Css
15	National Semi	LM5576BLDT	Bare PC board with pre-soldered IC	
16	National Semi	LM5576MH	Package=TSSOP_EXP_PAD	U1
17	ON Semiconductor	MBRS3100T3G	Io=3A VFatIo=0.62V	D1
18	Coilcraft Inc.	SER2918H-333KL	L=33uH, R=0.0026 ohms	L1
19			4.3V, 0.5w zener diode	D2
20			27 ohm 0.25w	R2
21			10 µF 10V	C1

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Bill of Materials

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- DATA HOLD Function
- `FUNC' key manually holds the current reading
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- Power Supply: 3V Lithium Battery (CR2032) 1pc

Resistance Ranges:
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Capacitance Ranges:
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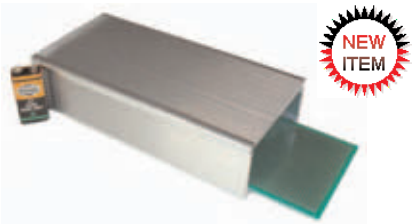

Item # 17-10A	Item # 17-10B	Item # 17-10C
Outside Dimensions 70 x 32.5 x 152.4 mm 2.75 x 1.27 x 6 in	**Outside Dimensions** 80 x 37.5 x 179 mm 3.14 x 1.47 x 7.04 in	**Outside Dimensions** 100 x 47.5 x 203 mm 3.93 x 1.87 x 7.99 in
Inside Dimensions 55 x 25 x 152.4 mm 2.16 x 0.98 x 6 in	**Inside Dimensions** 65 x 30 x 179 mm 2.55 x 1.18 x 7.04 in	**Inside Dimensions** 85 x 40 x 203 mm 3.34 x 1.57 x 7.98 in
PCB Size 50 x 20 x 152 mm 1.95 x 0.78 x 5.98 in	**PCB Size** 60 x 25 x 179 mm 2.36 x 0.98 x 7.04in	**PCB Size** 80 x 35 x 203 mm 3.14 x 1.37 x 3.98 in
Perfboard Specifications 20 x 57 plated thru holes on 0.1in centers on double-sided FR-4 board	**Perfboard Specifications** 24 x 67 plated thru holes on 0.1in centers on double-sided FR-4 board	**Perfboard Specifications** 32 x 77 plated thru holes on 0.1in centers on double-sided FR-4 board
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Item # 15-8	Item # 15-3	Item # 15-5	Item # 15-1
Outside Dimensions 100x75x36 mm 3.93x2.95x1.14 in	**Outside Dimensions** 120x80x41 mm 4.72x3.14x1.6 in	**Outside Dimensions** 150x100x53 mm 5.90x3.93x2.08 in	**Outside Dimensions** 190x122x61 mm 7.48x4.80x2.40 in
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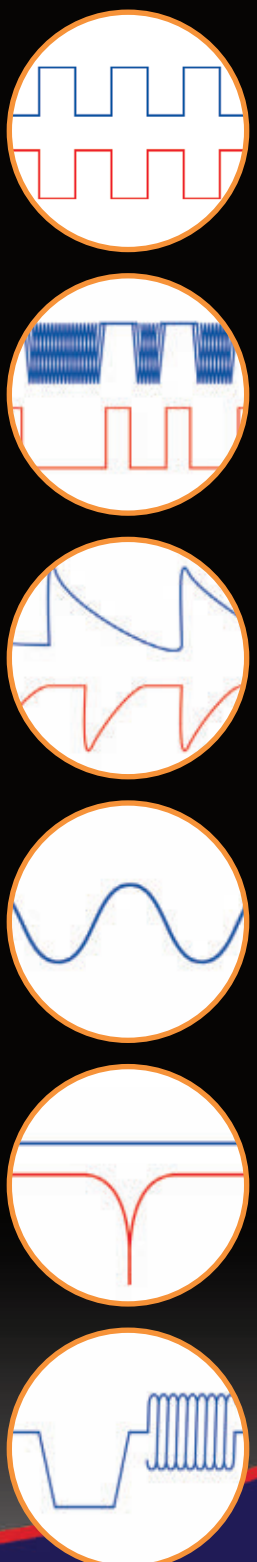

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- **Measure signal characteristics such as frequency and duty cycle**
- **Track I/O pin states with 22 logic modes**
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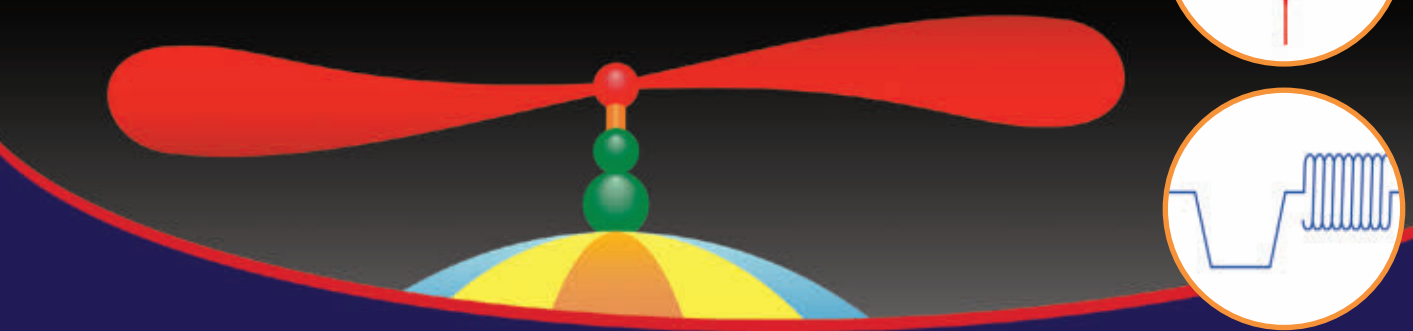
With the Propeller chip's counter modules, integrating multiple repetitive parallel processes into time-sensitive deterministic applications is suddenly simplified.

For prebuilt Propeller code objects, tutorials, and example applications, go to **www.parallax.com/go/counters**



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